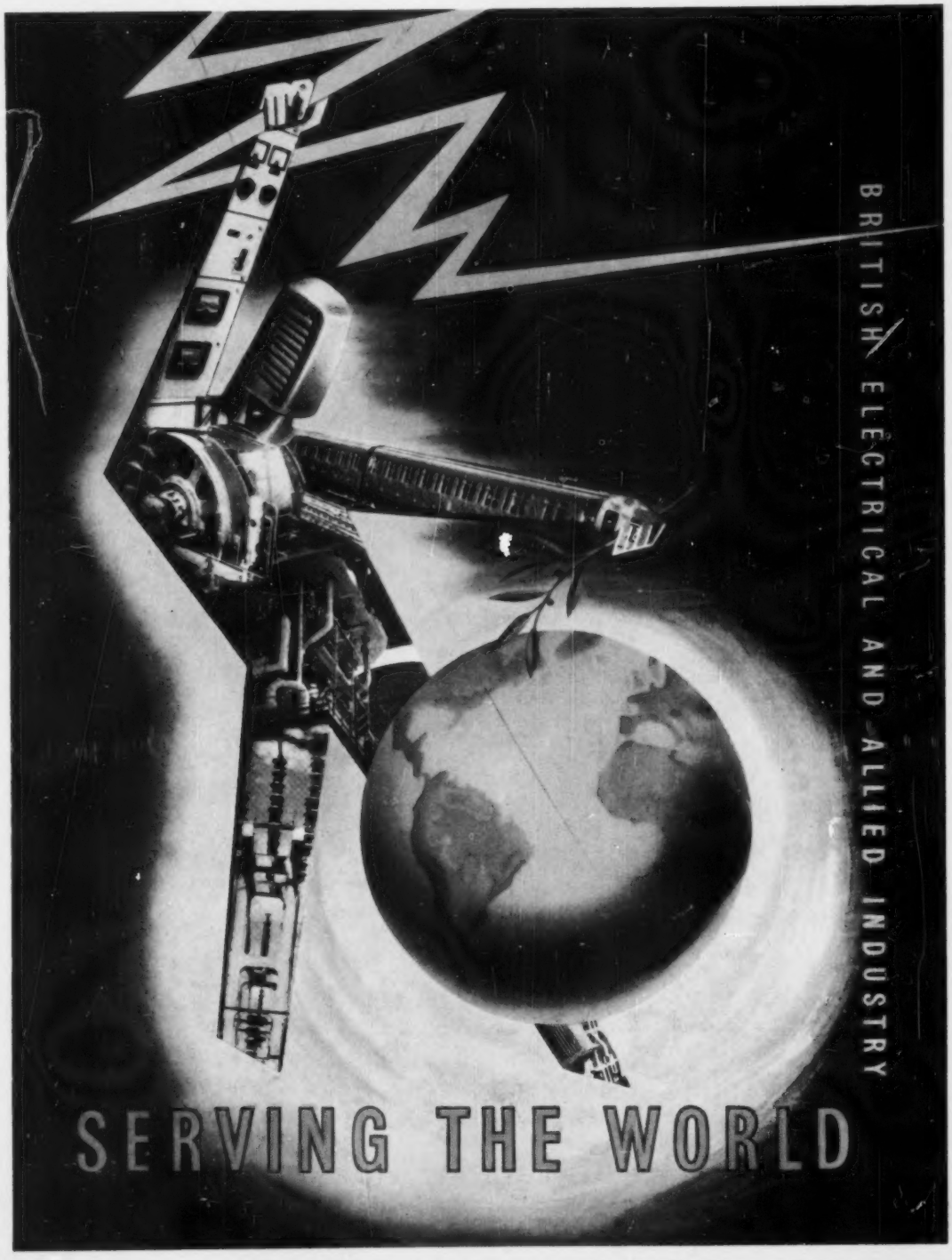
FEBRUARY 1958

THE BEAMA JOURNAL



A QUARTERLY REVIEW OF

BRITISH ELECTRICAL AND ALLIED ENGINEERING

Contents

	1	Editorial Calder Hall—and after: The new CEGB: Lord Kelvin—1824–1907: Cover illustration
	3	Brussels: April 17 to October 19, 1958
	6	The 1958 British Electrical Conference
J. A. Thomas, BSc, AMIEE; F. A. Roberts, AMIED; D. Legg, BSc, Graduate IEE	7	The application of high-speed cine-photography to switchgear research and design
	15	Electricity tells its story At the Building Centre and the Science Museum
K. F. Sander, PhD, AMIEE	17	The electrolytic tank analogue
	24	Notes
R. I. Tompsett	27	Industrial cooking equipment Its design, development, and application
	31	Progress in semi-conductors and metal rectifiers
	33	Railway electrification forges ahead New diesel-electric locomotives handed over
	36	The nuclear propulsion of ships A review of the present position
	38	New equipment and processes
	40	Book reviews
	44	Index to advertisers

Editor: **Sam Black** *Technical Editor:* **John Dyer**

Published by The British Electrical and Allied Manufacturers' Association (Incorporated), 36 Kingsway, London, WC2. *Telephone:* HOLborn 0502. *Telegrams:* Perisirius, Westcent, London.

Annual subscription: 10/- post free. Single copies, 2/6. Advertising rates on application. Publication dates: first of November, February, May, and August.

The Association does not necessarily endorse statements made in the Journal.

THE BEAMA JOURNAL

A QUARTERLY REVIEW OF BRITISH ELECTRICAL AND ALLIED ENGINEERING

Volume 65 : Number 1 : February 1958

Editorial

Calder Hall—and after

Much has been said and much written, both in the popular and the technical press, about Calder Hall. Out of the many we select for its special significance a comment in *The Economist* last month, in which it was stated that in twelve months from now it should be possible to classify the outstanding scientific event in each of the three preceding years as follows: 1956, the opening of Calder Hall; 1957, the launching of Sputnik; 1958, the control of fusion.

It is particularly noteworthy that two of these three major developments are British—a remarkable record by any standards, and a particularly praiseworthy achievement reflecting the utmost possible credit on British brains and pertinacity.

For the moment, we are not concerned with the well-nigh limitless possibilities of thermo-nuclear fusion. The historic announcement that British atomic scientists and engineers at Harwell have now mastered the secret of the control of fusion and have successfully produced temperatures of the order of 5 million degrees C in 'Zeta' was made just as this issue was going to press, and further comment will have to await our next issue.

But the influence and example of Calder Hall are far reaching, and are already producing a resounding impact on British export business.

The first customer—Italy—is already 'on the books', so to speak. A British firm has received a letter of intent from Ente Nazionale Idrocarburi of Rome to negotiate the construction of nuclear power stations in Italy and to conclude a long-term agreement for mutual cooperation on the design and development of power reactors. Throughout the negotiations leading up to this happy conclusion, both sides have had the cooperation of the United Kingdom Atomic Energy Authority.

The first station to be constructed under this arrangement will have an output of 200 MW, and will involve the manufacture in Britain of considerable quantities of plant.

Another Italian company, SENN (Società Elettronucleare Nazionale of Rome), has retained the services of a London firm of consulting engineers to provide technical services in connexion with the building of a 150-MW station to be sited about 100 miles north of Rome—the first time, it is believed, that British consultants have been engaged for an overseas nuclear power station project.

Although a slight hitch has developed in connexion with the contract for the first German nuclear power plant under the auspices of RNE (Rheinisch-Westfalisches Elektrizitätswerk), another project has been successfully concluded between the Governments of Great Britain and the Federal Republic of Germany and the firms concerned in both countries for the design and engineering of a high-flux materials testing reactor similar to 'Dido' at Harwell. The reactor is intended for the Atomic Research Establishment of the Land-Nordrhein-Westfalen, and will probably be installed near Düsseldorf.

Japan has already taken a keen interest in Calder Hall, which was visited by a delegation from the Atomic Energy Commission (Kagaku-Gijutsu-Cho of Tokyo) last year. Following a favourable report in which it was stated that problems affecting the insulation of the plant against earthquakes had been solved, a mission from the Japan Atomic Co came to this country last month to prepare for the purchase of a power plant of the Calder Hall type, and a loan of some £13 m is being sought from the World Bank to finance the deal.

South Africa, too, is looking to Britain. Dr van Rhijn, Minister for Economic Affairs and Mines, who recently visited both Britain and USA, said that he had been very impressed by Calder Hall and that it would almost certainly be used as the model for any atomic power station in the Union. A committee was at present studying the question, but a decision was not likely before April.

And so Calder Hall has written the first chapter of what must be a continuing story of British enterprise and leadership. Nor are these immensely valuable export orders the sum total of the benefits likely to accrue. The exchange of information, and the projected collaboration in scientific and technical research and development, are bound to lead to further improvements in subsequent nuclear projects, both in this country and overseas.

The new CEGB

The Central Electricity Authority, which came into being on 1 April 1948, literally went out with the old year and was succeeded on 1 January 1958 by two new bodies: The Electricity Council and the Central Electricity Generating Board. The change was brought about by the Electricity Act of 1957, following the recommendations of the Herbert Committee that there should be an organization in which responsibility for the generation of electricity and its supply in bulk was divorced from general responsibility for the industry as a whole.

The CEGB has now made it known that it proposes to devolve more responsibility, autonomy, and power on the provincial establishments—a move perhaps dictated by the experience of the past ten years of more tightly centralized control. The existing Generating Divisions will continue as operational management units and will be grouped in the following five regions under Regional Directors: North Eastern and Yorkshire; Midlands and East Midlands; Eastern, London, and South Eastern; Southern, South Western, and South Wales; North West, Merseyside, and North Wales. Each region will have a Regional Executive Committee which will administer the region within the broad policy rulings laid down by the central board.

Since the development of the industry makes it impossible to secure a uniform load on the construction staffs of the eleven divisions or even of the five proposed regions, the board plans to establish three separate 'Engineering Project Offices': North—working for the North West, Merseyside, and North Wales, North Eastern and Yorkshire areas; Midlands—working for the Midlands, East Midlands, and South Wales areas; London—working for the London, Eastern, South Eastern, Southern, and South Western areas, but with flexible boundaries which will enable them, when convenient, to undertake projects in adjoining areas.

Their functions will be to undertake the construction of new stations or major extensions to existing stations and the associated switching stations. Nuclear as well as conventional stations will come within their scope.

In taking over a going concern, so to speak, the CEGB has an easier task than that which confronted the CEA on its formation ten years ago. Some measure of what the CEA has achieved during that time is afforded by the record. For example, the peak demand met by the authority during 1957 was 19,311 MW on 16 December —and this was supplied at full voltage and frequency. This was 1643 MW above the peak load at the beginning of the year, and over 124 per cent greater than the peak demand of 8607 MW recorded for England and Wales during the year before the CEA came into being.

In its last year of operation, the Authority achieved the installation of new generating plant having an aggregate capacity of 1903·5 MW—between 3 and 4 times the amount commissioned during its first year. If one then adds new plant commissioned by the South of Scotland Electricity Board, a total installed figure of some 1993 MW is reached in the area of the former British Electricity Authority. The cost of electricity to the consumer has been held to an increase of about 30 per cent despite very much greater increases in the costs of fuel and raw materials generally, while the overall cost of new plant per kW installed has been maintained at the 1948 level.

Great credit is justly due to the CEA and all concerned with these achievements—and not least to the manufacturers of the generating and associated equipment, whose close and continuous cooperation with the Authority has been a major factor. That it will be no less so in future can be taken for granted, and by designing and constructing boilers for higher steam pressures, and larger turbo-alternators of 120 and 200 MW capacity, they have already set the pattern for even greater generating efficiency in the future.

Lord Kelvin—1824-1907

Last December marked the fiftieth anniversary of the death of one of the greatest British scientists of the nineteenth century: William Thomson, Lord Kelvin. A man of unique intellectual attainments, he stood out in his time as a rare combination of mathematician, physicist, and practical technologist, equally at home in the realms of natural philosophy or practical invention.

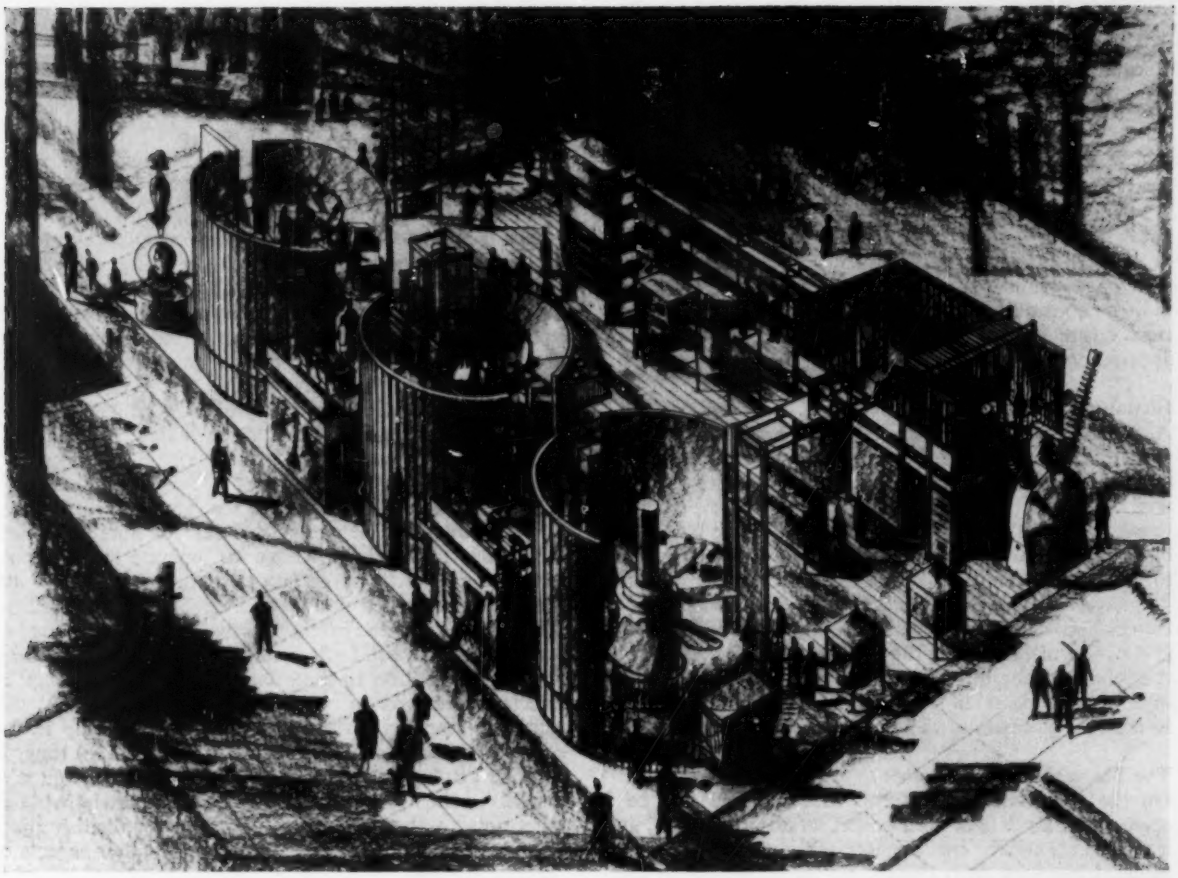
He can truly be said to have laid the foundations of the British scientific instrument industry. Following up Faraday's work in sending electric signals through long submarine cables, Thomson devised many improvements in cable construction, and better instruments—notably the mirror galvanometer and the siphon recorder—for the detection of the minute signal currents.

His technical studies on telegraphy pointed to the need for better, more versatile and accurate measuring instruments than were then available. 'The basis of all scientific knowledge is measurement' was a precept he never ceased to emphasize to his students, and this led to his invention of a wide range of measuring instruments and, later, to his outstanding work in the determination of electrical standards, which led to the formation of a special committee of the Royal Association for this purpose.

Thomson was elected President of the Royal Society in 1890; created a baron, taking the title of Lord Kelvin of Largs, in 1892, and appointed to the Order of Merit on its institution in 1902. He died on 17 December 1907, and was buried beside Newton in Westminster Abbey.

Whether Kelvin be remembered principally as the philosopher and physicist who made fundamental contributions to the establishment of thermodynamics; as an outstanding teacher who held the chair of natural philosophy at Glasgow University for 53 years; or as the practical electrical technologist and inventor of some 70 patents, his name and fame are secure among electrical engineers for all time.

Cover illustration. *We have adopted as the front cover of this month's issue a photograph of the striking 5-colour design used for the cover of the souvenir publication specially produced for the Brussels World Exhibition. This 48-page book entitled 'Serving the World' is being sent overseas and will also be available on the British Electrical and Allied Industry's stand.*



An artist's impression of the Electrical and Allied Industry's exhibit described in detail on pages 4 and 5. Its size can be gathered from the figures of the visitors at ground level and on the upper floors of the Chambers of Energy

Brussels: April 17 to October 19, 1958

IN portraying its theme of 'Serving the World', the British Electrical and Allied Industry has an impressive story to tell, and the manner and scale of its presentation at the Brussels World Exhibition of 1958 will be fully in keeping with the importance of its message.

The Industry's collective exhibit is titled 'Power for Progress' and will occupy a central position in the British Pavilion. It will be the largest single exhibit, covering 5000 sq ft (46·5 m²), and will occupy approximately one-eighth of the total exhibition area in the pavilion.

The object of the Industry's participation in the Brussels World Exhibition is to maintain the international prestige of the Industry and to stage an exhibit which will interest and impress the 40 or 50 million visitors expected at the exhibition—including many trade delegations and official representatives from the Governments of the world.

The scope and general layout of the exhibition as a whole were described in detail in the August 1957 issue of THE BEAMA JOURNAL. On this and the following two pages of this issue, the reader is taken on a conducted tour, as it were, of the British Electrical and Allied Industry's Exhibit, and it is hoped that the detailed descriptions, in conjunction with the artist's impression of the exhibit as a whole at the top of this page, will convey an adequate idea of the effective and quite spectacular presentation which has been achieved.

Much care and thought have equally been given to the administration and information aspects of the exhibition, so that (*a*) interested visitors will have their inquiries promptly and competently handled without any handicap of language, and (*b*) that all business inquiries will be efficiently routed to the participating associations and member-firms without delay.

Overseas buyers and trade delegations will also be invited to make arrangements at the Industry's information bureau to visit factories, plants, and installations in Britain and so see at first hand and on a life-size scale the virile industry portrayed in microcosm at Brussels.

There are thus good grounds for hope that the aims of the organizers will be accomplished, and that the beneficial effects of Brussels in 1958 on the development of world trade and peaceful coexistence will continue long after its gates have closed for the last time.

Power for Progress

DETAILS OF THE INDUSTRY'S EXHIBIT

THE exhibit has been designed so as to form a composite pattern which will almost constitute a small pavilion within the British Industries Pavilion. Approximately half the area will be built up to a height of over 20 ft (6·1 m), providing a considerable amount of 'first-floor' accommodation raising the effective floor area of the exhibit to approximately 6500 sq ft (60·4 m²).

Chambers of Energy
Along one side will be the three chambers of energy which, together with the connecting links between the chambers, will form a striking pattern of structures which will immediately attract the notice of visitors. Each of these cylindrical chambers will be about 20 ft (6·1 m) in diameter and there will be a 70 ft (21·3 m) long walk through the chambers. Prominent title panels in many languages will be on the outside walls of the chambers of energy and will include two large murals, each 11 by 9 ft (3·4 by 2·7 m), depicting the contribution of electricity to the advancement of mankind. It will be possible to see into certain parts of this solid structure and obtain interesting glimpses of the visitors inside.

The Thermal-power Chamber
On the right-hand side of this first chamber will be 3 special models: a coal-fired boiler, an oil-fired boiler, and a heat exchanger. On the left will be a large three-dimensional flow chart illustrating the conventional thermal method of generating electricity. In the first link, on the way to the second chamber, there will be a large model of a steam power and industrial installation on one side, and a turboalternator model on the other side.

The Nuclear-energy Chamber
Here there will be special sound and lighting effects calling attention to Britain's lead in the use of nuclear energy for peaceful purposes. The exhibits will include an animated nuclear reactor model; a large three-dimensional animated display illustrating a typical Calder Hall type station; and four paintings in oils, specially painted by Claude Buckle, of the new nuclear power stations now being built in Britain.

The Water-power Chamber
In the link before the third chamber will be a sectional working model of part of an impulse turbine, and a large diorama of a typical pumped-storage scheme. In the chamber itself, the chief exhibit will be a very large propeller runner which will be about 18 ft (5·5 m) in diameter and will nearly fill the chamber. This impressive centre-piece will be supplemented by an animated sectional model of a hydro-electric set illustrating how the propeller runner is used in practice. Here, too, will be an extensive photographic display depicting the different methods of power generation.

Transmission and Distribution
The story of transmission and distribution will be told by a variety of items of equipment and models. These will include: a single-phase, 275,000 kV, oil-filled circuit-breaker; an air-cooled circuit-breaker installation model; a model of one of the Central Electricity Generating Board's new control centres; a large animated layout showing the way in which electricity leaves a power station and is transmitted through the grid and is transformed for the use of different types of consumer in homes, factories, offices, and on the land. In this section there will also be a three-dimensional display of cables arranged with the cooperation of the Cable Makers' Association.

Electric Traction
Electric traction for road, rail, sea, and air will be portrayed. An overhead gantry will carry a number of sets of railway signal lights which will operate in an appropriate sequence. A large model of the new P & O all-electric liner, which is at present being built at Belfast, will demonstrate the extent to which electricity is used at sea. This model will be flanked by a number of telephones giving information in three languages about the ship. A special model of a Bristol 'Britannia' aircraft will similarly emphasize the importance of electricity in the air. Both these models will be about 9 ft (2·7 m) long. A massed display of electric and diesel-electric locomotive models in the liveries of many overseas countries will call attention to the world-wide markets for British locomotives, and photographs will illustrate other aspects of electric traction.

Electricity in the Service of Industry
Space will not allow the actual demonstration of any electrical industrial processes, but the extent to which practically all basic industries are dependent on electricity for modernization and efficiency will be high-lighted by an ingenious animated three-dimensional 'A to Z' exhibit. Photographs of electric furnaces, welding, and other industrial electrical processes will be shown and a display of examples of fine British workmanship will also be included.

Electronics and Radio Navigation
Britain's prominent part in the invention and development of radar and electronics will be stressed by a special electronics exhibit which will have as its central feature a huge 18 ft (5·5 m) high valve tower made up of over one thousand valves of British manufacture which are used internationally in industry, medicine, communications, scientific research, and in the home. There will also be a working exhibit of a marine radar scanner linked to a viewer display which will simulate actual working conditions at sea.

The Domestic and Radio Section
On the upper floor of the first two chambers of energy and the two connecting links will be the Domestic and Radio Section, covering about 900 sq ft (83·6 m²) and reached easily by two short staircases. This section will take the form of a well-furnished showroom to provide

a suitable setting for a representative display of British domestic electrical appliances, radio and television receivers. There will be about 100 items exhibited in this section by 28 firms. This upstairs area will be easily visible from all over the British Industries Pavilion and from the open balcony at each end an interesting panoramic view will be obtainable.

There will be an information desk in this Section where inquiries will be dealt with and where copies of *Electricity in the Home* will be distributed. An electronic eye will count visitors to the Domestic and Radio Section and it is planned to give special gifts to the 100,000th visitor and so on.

Overseas Development Schemes

Throughout the exhibit the emphasis of captions and pictures will be on the part that the Industry has played in overseas development. In a special overseas section six features will exemplify typical overseas schemes carried out by British engineers and manufacturers. The features chosen from the very many considered are the Owen Falls Scheme; the Vancouver undersea power link; the Lisbon–Oporto telephone system; railway electrification in Brazil; a feature depicting British transformers *en route* to the Tennessee Valley Authority; and a special skip-winding mining feature. Adjoining this overseas section will be a large three-dimensional map of the world showing where £1000 m value of exports from the industry have been supplied in the last four years. Here, too, it will be emphasized graphically that Britain has led the world in the development and use of electricity from Faraday to Calder Hall, and onward to the utilization of nuclear fusion for peaceful uses.

Lighting

As befits an exhibit staged by the electrical industry, full use is being made of modern methods of lighting for the displays and to provide additional decorative effects where appropriate. Special arrangements are being made to keep the exhibit illuminated when the Pavilion closes, but the Exhibition grounds remain open so that the contents of the Pavilion will be continuously visible to visitors.

Focal Points

Eye-catching features in various parts of the area—such as a series of three large glass bulb rectifiers, lightly activated; a display of water-tubes symbolizing steam power; the large circuit-breaker; the valve tower and the radar scanner—will give visitors to the exhibit a sense of size and prevent any possibility of the feeling of miniaturization which can so easily result from a collection of numerous scale models.

Technical Inquiry Office

One complete corner of the exhibit will consist of the Technical Inquiry Office block. Here, on the ground floor, an efficient staff of interpreters and technical men (lent on a rota by member-firms) will deal with all inquiries, and visitors will be able to read technical journals and consult electrical books of reference.

On one inside wall of the office will be a display of oil paintings lent by the Telecommunication Engineering & Manufacturing Association. This will be titled 'British Leadership in Telecommunications', and the paintings, which are by Francis B Savage, depict notable British 'firsts' in this field.

Above this office a comfortable lounge will provide a suitable venue for discussion and entertaining.

A large panel on the outside wall of the Technical Inquiry Office will bear the names of the associations and firms supporting the collective exhibit and this list will be repeated inside the office. All the actual exhibits and models shown will be anonymous except in the Domestic and Radio Section, where the individual items will be captioned.

Publications

The special publications prepared for Brussels include: (1) *Serving the World* (50,000 copies; 48 pages; 11 by 8½ in (279 by 216 mm); in full colour). (2) *Electricity in the Home* (100,000 copies; in English, French, and German; 44 pages; 8¼ by 5¼ in (210 by 133 mm); in 2 colours. (3) A special souvenir publication in full colour by the Water-Tube Boilermakers Association. (4) *British Leadership in Telecommunications*—in full colour, published by the Telecommunication Engineering and Manufacturing Association. (5) The Fourth Edition of the *BEAMA Catalogue*. (6) A special leaflet—printed in six languages—describing the Industry's Exhibit, the 1958 British Electrical Conference, and giving information for buyers wishing to visit British factories or works after visiting Brussels.

Planning and Administration of the Exhibit

The BEAMA took the initiative in planning this exhibit but was soon joined by six other trade associations: the Water-Tube Boilermakers Association, the British Radio Equipment Manufacturers' Association, the Cable Makers' Association, the Electric Light Fittings Association, the Radio Communication and Electronic Engineering Association, and the Telecommunication Engineering and Manufacturing Association, who have all played an active part in the project. The organizing Committee, under the chairmanship of Mr D Maxwell Buist, includes representatives of the associations and firms supporting the collective exhibit. The detailed planning has been carried out by the Working Committee, and many other committees and specialist advisory panels have contributed to the success of the project.

The exhibit has been designed by Design Research Unit under the direction of Misha Black, OBE, RDI, PPSIA, MInstRA. Associated architect: Kenneth Bayes, FRIBA, MSIA. Assistant architects: Christine Durell, ARIBA, and Aaron Romanovsky, BID. Associated display designers: Ronald Armstrong, J Beresford Evans, MSIA, C Wycliffe Noble, ARIBA, Robert Wetmore, MSIA. Typographical designer: Robert Perritt, DA. Consulting Engineer: J A Neill, ACGI, BSc(Eng), DIC, AMICE. Quantity Surveyors: C E Ball & Partners. General Contractor: F W Clifford Ltd. Shipping Agents: Beck & Pollitzer Ltd.

The 1958 British Electrical Conference

BRUSSELS: 16 AND 17 MAY 1958

Sir Gordon Radley, KCB, CBE, PhD Eng, Director - General of the British Post Office

Sir John Cockcroft, OM, KCB, CBE, FRS, Director of the Atomic Energy Research Establishment

Of the many international congresses to be held during the six months of the Brussels Exhibition, one of the most important is undoubtedly the British Electrical Conference arranged for Friday and Saturday, 16 and 17 May. The Conference has been officially approved by the Belgian authorities and enjoys the patronage of the Commissariat-Général of the Belgian Government.

In keeping with the theme of the British Electrical Industry's exhibit—'Serving the World'—the purpose of the Conference is to present to the representative world audience an authoritative report of outstanding British achievements in the electrical field.

The programme for the conference is as follows:

Thursday 15 May
Registration from 6 pm at the Palace Hotel, Brussels.

Friday 16 May
Registration from 9 am to 10 am in the Exhibition Auditorium. 10 am to 12 30 pm (also in the Exhibition Auditorium), Sir Gordon Radley, KCB, CBE (Director-General of the British Post Office), will read a paper: *Communications between Nations and Peoples.*

Saturday 17 May
3 pm to 5 pm in the Exhibition Auditorium: Sir John Cockcroft, OM, KCB, CBE, MIEE, FRS (Director, Atomic Energy Research Establishment, Harwell), will read a paper: *Nuclear Energy, The Power of the Future.*

5 30 pm to 7 pm in the Exhibition 'Palais d'Élégance': Reception for members of the Conference.

The president of the Conference will be Sir Vincent de Ferranti, MC (President of the BEAMA), and the following eminent personalities in the British electrical industry have accepted invitations to hold office as vice-presidents: Sir Lawrence Bragg, CBE, MC, FRS (Director, Davy Faraday Laboratory, The Royal Institution); The Rt Hon Viscount Chandos of Aldershot, DSO, MC (Chairman, Associated Electrical Industries Ltd); G Darnley-Smith, CBE (Chairman, Radio Industry Council); Sir Thomas Eades (Chairman, The Telecommunication Engineering and Manufacturing Association); Sir Claude Gibb, KBE, FRS (Chairman and Managing Director, C A Parsons & Co Ltd); Sir Kenneth Hague (Managing Director and Deputy Chairman, Babcock & Wilcox Ltd); Sir Harold Hartley, KCVO, CBE, MC, FRS (Past-Chairman, OEEC Nuclear Power Commission); Sir Christopher Hinton, KBE, FRS (Chairman, Central Electricity Generating Board); J O Knowles (Chairman, The British Electrical and Allied Manufacturers' Association); W Messer (Director, International Combustion Co Ltd); The Rt Hon Lord Mills, KBE (Minister of Power, Her Britannic Majesty's Government); Sir George H Nelson, Bart (Chairman, The English Electric Co Ltd); Sir Harry Railing (Director, The General Electric Co Ltd); R W C Reeves (Chairman, The Cable Makers Association); J B Woodeson, OBE (Chairman, The Water-Tube Boilermakers Association).

One of the most valuable features of the Conference will be the opportunity it affords for discussion between leading scientists and manufacturers from many different countries. To that end, invitations have been sent to scientific and professional bodies both in Britain and overseas, and a large attendance is expected from among the many men and women in all countries who are interested in the generation and utilization of electricity.

The latest date for the return of registration forms from overseas countries is 31 March next, although it will help both the organizers and intending delegates if the forms are returned as soon as possible. Registration fee for overseas members is £4 sterling (or equivalent), and £2 sterling (or equivalent) for ladies accompanying members. These fees include the reception on the Saturday evening and free admission to the Exhibition during the Conference.

Hotel accommodation will be arranged for overseas members by LOGEXPO, who will give priority to those attending the Conference. Applications for accommodation should be made direct to LOGEXPO, 35 rue Belliard, Brussels, Belgium. Telegraphic address: LOGEXPO-BRUXELLES.

Applications for registration forms and all inquiries about the Conference should be sent to the Organizing Secretary, 1958 British Electrical Conference, 36 Kingsway, London WC2. Telephone: Holborn 0502; Cables: Perihelion, Westcent, London.

The application of high-speed cine-photography to switchgear research and design

J A Thomas, BSc, AMIEE; *F A Roberts*, AMIED; *D Legg*, BSc, Graduate IEE*

HIGH-SPEED cine-cameras are of great value in switchgear research and design since they make it possible to see what actually happens in a switch or circuit-breaker during the fraction of a second in which it operates. In particular they enable the rapidly changing appearance and movement of the arc drawn between the contacts of a circuit-breaker to be studied in detail, and they often indicate ways in which the arc-control devices can be improved. Without high-speed cine records it was necessary to try to deduce the behaviour of the arc from the oscillograms of current, voltage, and pressure, and by visual examination of the burning caused by the arc, and much guesswork was involved. High-speed cine-photography of the mechanical parts of a circuit-breaker is also often of value, as, for example, in detecting any rebound of the moving contacts or mal-operation of the various links, springs, and other components of the operating mechanism.

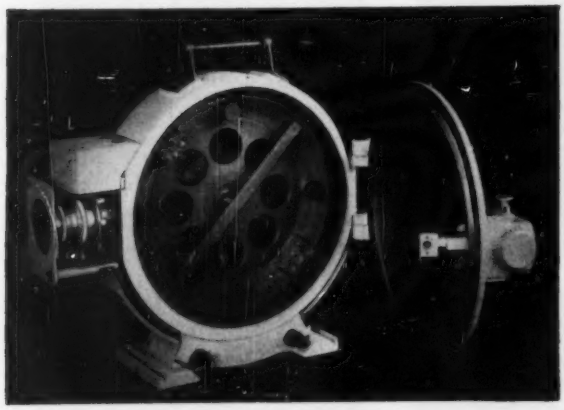


Fig 1. Rotating-prism cine-camera

To enable the arc and parts inside a circuit-breaker to be photographed it is of course necessary to make the surrounding parts of transparent material, or to provide transparent windows in them. Perspex is widely used because, in addition to its suitable optical and mechanical properties, it is able to withstand the high temperature of the arc.

The arc is highly self-luminous and presents no difficulty as far as illumination is concerned. Other parts may need special illumination, especially if they are to be photographed at the same time as the arc. Colour film is sometimes of value, as, for example, to distinguish between the core of the arc and the surrounding aureole of ionized gas.

Cameras

Various forms of high-speed cine-camera are used. One, which employs a rotating prism to form the individual image frames on a film moving at constant speed, is shown in Fig 1. The film is mounted round the periphery of a drum which is driven by a motor and in turn drives the prism situated between the lens and the drum. The maximum taking-rate is 2000 frames/sec, and the number of frames obtainable on the film is 160.

Another form of camera has a stationary image-dissector between the taking lens and the film. Fig 2

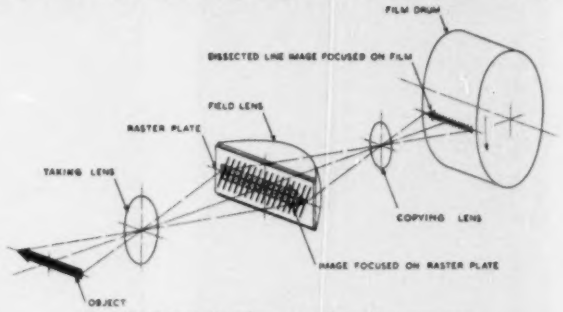


Fig 2. Principle of raster-plate cine-camera

shows the essentials of such a camera, in which the image-dissector consists of an opaque plate with a series of parallel slits slightly inclined to the direction of movement of the film. The figure shows the dissected image received on the film at a particular instant, but as the film drum rotates, the record on the film becomes a series of tracks along its length. The film record is therefore not directly intelligible. To obtain a picture from the film, the camera is used in reverse as a projector, or a projector having an identical raster-plate is used, and the picture so obtained is made up of parallel slanting lines corresponding to the parts of the full image that fell on the slits in the raster-plate during taking. Fig 3 shows one such camera capable of a taking-rate equivalent to 800,000 frames/sec.

Application to Oil-break Circuit-breakers

PHOTOGRAPHING THE ARC AND THE BUBBLE

In an oil-break circuit-breaker the high temperature in the vicinity of the arc causes the oil to split into its components, most of which are gases. The gases form a bubble

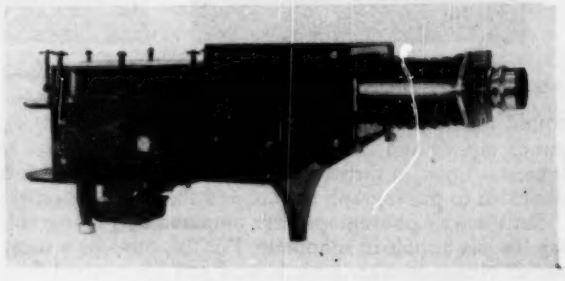


Fig 3. Raster-plate cine-camera

* A Reyrolle & Co Ltd.

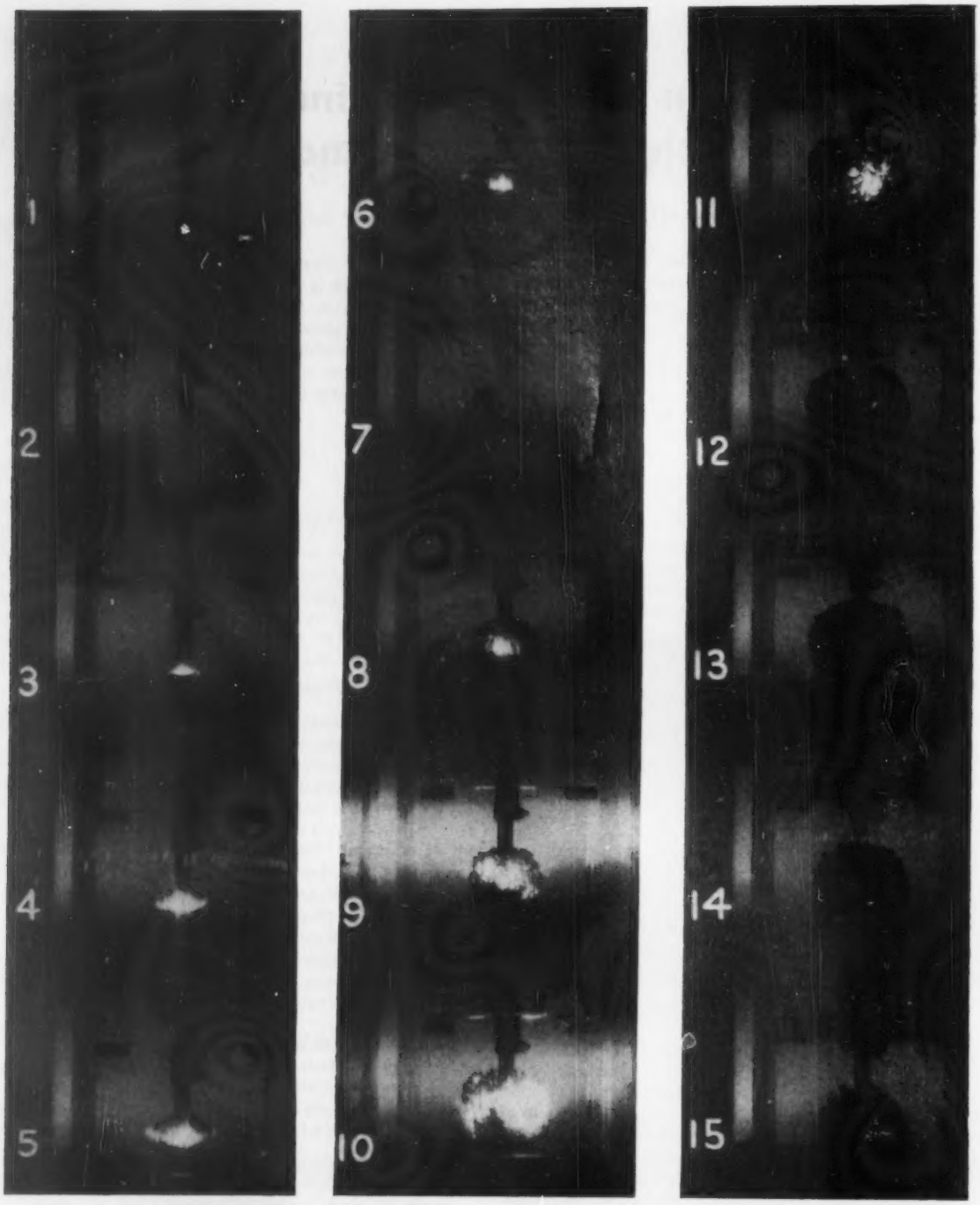


Fig 4. Cine-film of the arcing phenomena in a plain-break oil-break circuit-breaker. Taking speed: 500 frames/sec

round the arc, and if the current is large the bubble expands rapidly and sets up a high pressure which plays an important part in the extinction of the arc. It is therefore desirable to photograph the arc and the bubble together.

Satisfactory photographs are obtained by photographing the gas bubble in silhouette. For this purpose a transparent circuit-breaker tank is used and illuminated from behind. Fig 4 shows a series of consecutive frames from a cine-film of the arc and gas bubble in an experimental plain-break circuit-breaker that was illuminated in this way. The circuit-breaker, which was designed primarily for developing photographic techniques, was breaking 600 A at 250 V, 50 c/s, and the film was taken at 500 frames/sec using the rotating-prism camera shown in Fig 1. The first frame shows the contacts closed. In the second frame the contacts have just parted, and the third frame

shows the arc and the gas bubble forming. As the current continues to flow the bubble increases in size. Frame 7 occurs approximately at a current-zero, and the arc is finally extinguished at the following current-zero just before frame 12. The first current-zero occurs between frames 2 and 3. The rise in oil level as the bubble increases in size is noticeable from frame 10 onwards, and the surface of the oil becomes increasingly disturbed as the bubble collapses. The final two frames show that the large bubble is unstable and starting to break up into a number of smaller bubbles.

The bubble appears dark, because (*a*) it has an irregular surface, with the result that light from the external source of illumination is scattered at its rear surface, (*b*) much of the light that penetrates the rear surface is refracted away from the camera as a result of the different refractive indices of the bubble and the oil, and (*c*) the carbon that is also formed when the oil is split into its components absorbs light. The appearance of the arc is distorted by the bubble and partly obscured by the carbon present. A clearer picture of the arc may be obtained by causing it to form near a transparent wall. This is done automatically when the arcing phenomena in a circuit-breaker with a turbulator arc-control device are being photographed, since the arc is drawn near the wall of the turbulator.

OBTAINING A CINE RECORD OF ARC EXTINCTION IN A SMALL-OIL-VOLUME CIRCUIT-BREAKER

Considerable use has been made of high-speed cine-photography of the arc behaviour in small-oil-volume circuit-breakers. Fig 5 shows one phase of a 220-kV circuit-breaker and a rotating-prism camera in position for testing at a short-circuit testing station. The nearer of the two single-break units was modified for photographing the arcing phenomena in it. The arrangement is illustrated diagrammatically in Fig. 6. The upper porcelain insulator of the unit was removed. The cylindrical bakelized-paper circuit-breaker tank was replaced by one made of perspex. To prevent refraction at the curved surfaces of the tank from causing distortion in the picture obtained, cylindrical lenses made of perspex were clamped to the tank. To produce a parallel beam of light through the tank and then direct it into the camera, a spherical plano-convex lens was attached to each of the cylindrical lenses. The normal turbulator arc-control device made of hard fibre and Stabec plates was replaced by one made of perspex plates, designed to give the same internal configuration as the normal turbulator and adequate strength

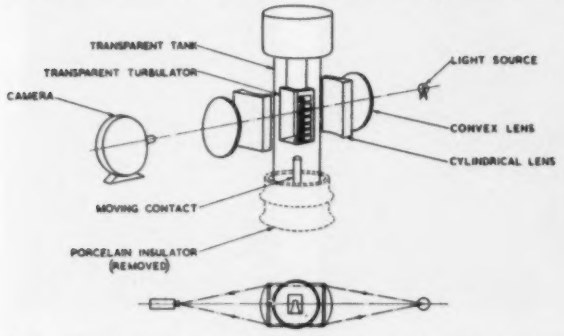


Fig 6. Sketch of the optical arrangement used in Fig 5. (The lenses shown spaced from the tank in the perspective view are actually clamped to it, as shown in the plan view)

to withstand the internal pressures set up during the breaking of short-circuit currents. Iron inserts were inserted in the plates as in the normal turbulator. The horizontal surfaces of the plates were painted black to prevent unwanted reflections, and all the vertical surfaces were highly polished. The oil used in the tank had a refractive index approximately equal to that of the perspex.

Fig 7 shows a series of 27 consecutive frames from a film taken at 1000 frames/sec while the single-break unit was breaking 4420 A at an applied voltage of 76 kV. The

Fig 5. Small-oil-volume circuit-breaker arranged for cine-photography of the arc during testing. (The circle indicates the camera)

arc is seen to have struck between the arcing contacts on the fourth frame. The gas bubble can be seen issuing from the first vent on the sixth frame. In the tenth frame the moving contact has moved down below the first vent and the arc can be seen in the vent. On later frames, *e.g.* frame 11, the arc appears to be broken into two parts at a vent. The arc is actually continuous at this time and it is thought that the apparent break is caused by the fact that the arc has been swept into the vent inside the bubble, but its light has been refracted away from the camera because of the differing refractive indices of the bubble and the perspex. Carbonization of the oil will also tend to obscure the arc. When the current is large and the arc intense, *e.g.* on frames 18, 19, 20, and 21, the arc can be seen in many of the vents. (Frame 19 occurs near a joint in the film.) Frame 13 occurs approximately at the first current-zero, hence the arc is not very intense and parts of it cannot be seen. The arc is finally extinguished at the second current-zero, immediately after frame 23.

USE OF CINE RECORDS

It is essential for successful operation of a turbulator that the gases exhausting through the vents should tend to

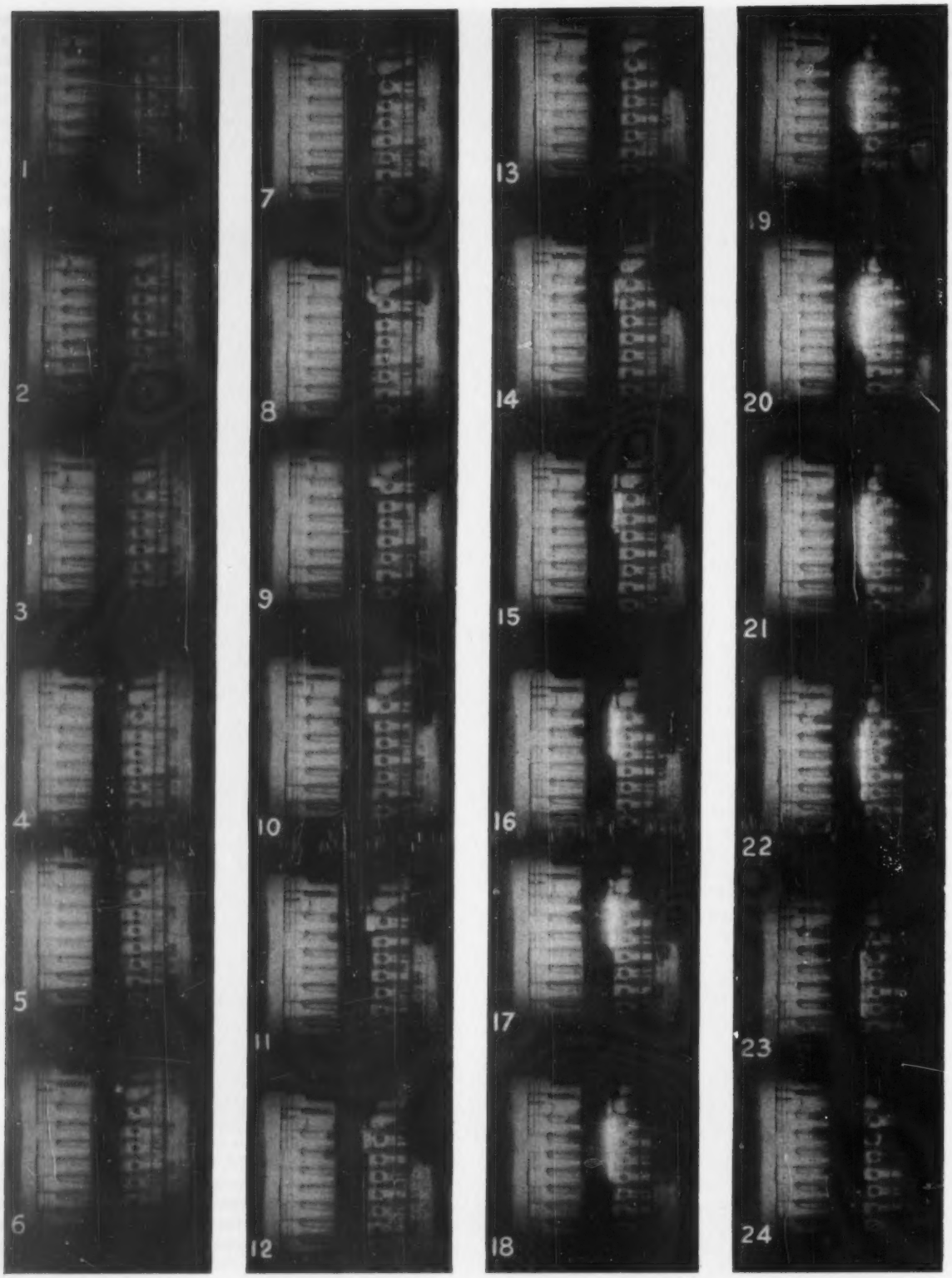


Fig 7. Cine-film of the circuit-breaker of Fig 6 breaking 4420 A. Taking speed: 1000 frames/sec. The sequence is continued in the 3 frames on the opposite page and in the sketch which corresponds to frame 10

sweep the arc into the vents. Hitherto it has been possible to determine whether this has occurred in any given turbulator only by examining the turbulator after the circuit-breaker has operated, to see where it has been burnt by the arc. High-speed cine-photographs, however,

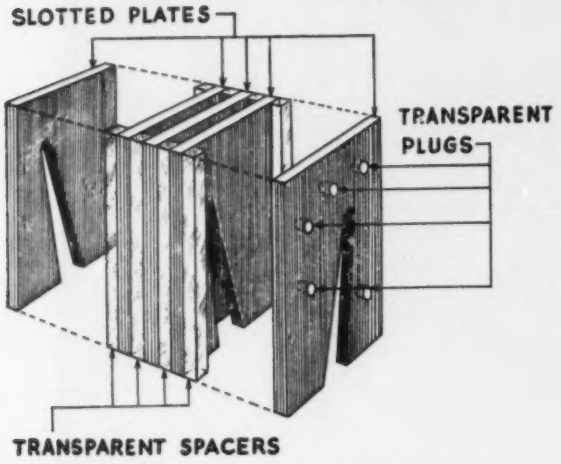


Fig 8. Principle of construction of a refractory-plate arc-chute for photographing the arc in it

allow it to be checked directly. For example, the film shown in Fig 7 shows that the arc is drawn close to the entrance to the vents and held against them and swept into them by the issuing gases.

Another important aspect of turbulator operation is that each vent should be cleared of oil by the gas before the arc reaches it. Researches have shown that the sudden vaporization of oil by a long arc can give rise to high impulse-pressures. In the vents the arc has the opportunity of lengthening itself appreciably, and if it did this by suddenly vaporizing the oil in the vent the impulse pressure set up might fracture the wall of the turbulator. Fig 7 shows that successive vents were cleared of oil by the gas before the arc was drawn down to them; for example, in frames 8 to 14 the frontier of the gas bubble travels right along the third vent, and so expels the oil from it, before the moving contact draws the arc down to that vent.

The horizontal partitions of the turbulator in Fig 7 are designed to ensure that the pressure of the gas inside the turbulator subjects the arc to a substantially horizontal force directed towards the vents. High-speed cine-photographs readily show whether such design features produce the effects intended.

The availability of oil in the turbulator at the end of a circuit-breaking operation can also be assessed from the cine-photographs. This is important in determining how soon afterwards a reclosure may safely be made.

Various formulae have been developed from time to time for calculating the pressures set up by the arc in oil-break circuit-breakers. In order to apply these formulae it is necessary to know the volume of gas liberated from the oil by the arc, and this can be obtained from the cine-photographs. Further, the gas volumes obtainable from

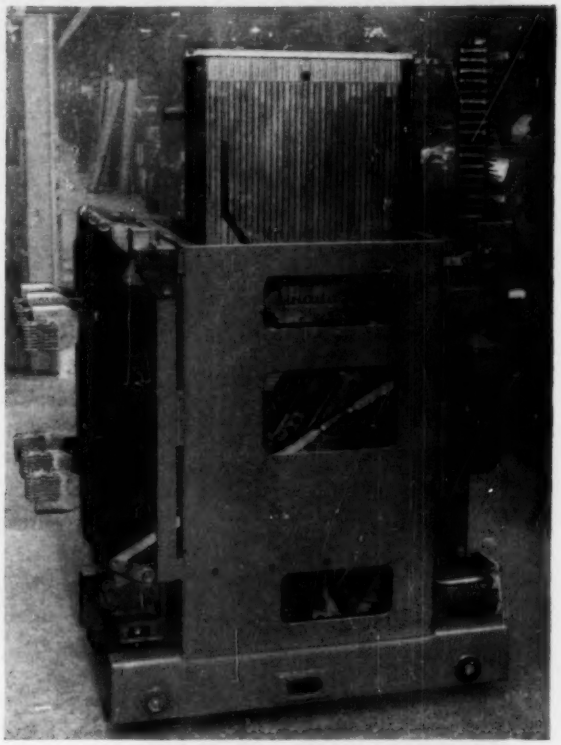
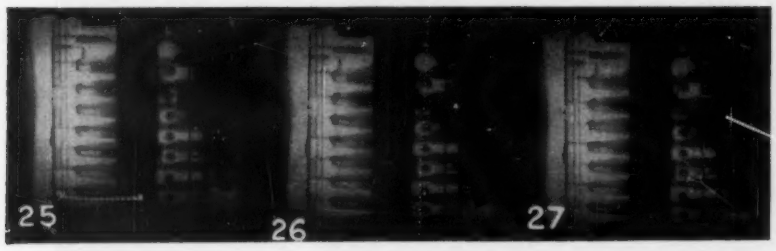


Fig 9. 3·3 kV air-break circuit-breaker with an arc-chute suitable for photographing the arc

the photographic record can be correlated with corresponding oscillograms of the current, voltage, and pressure to improve the accuracy of existing formulae and allow improved formulae to be developed.

Application to Air-break Circuit-breakers

In an air-break circuit-breaker the arc is drawn within an arc-chute, where it is lengthened and cooled until it becomes unstable and is extinguished. In an 11-kV circuit-breaker the final length of the arc may be 20 feet (6 m) or



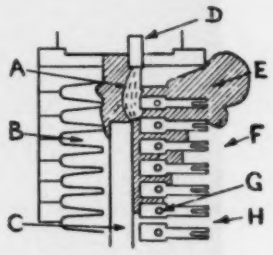


Fig 7 (contd). References in the sketch are: A—arc; B—oil; C—moving contact; D—fixed contact; E—gas bubble; F—oil; G—iron insert; H—vent

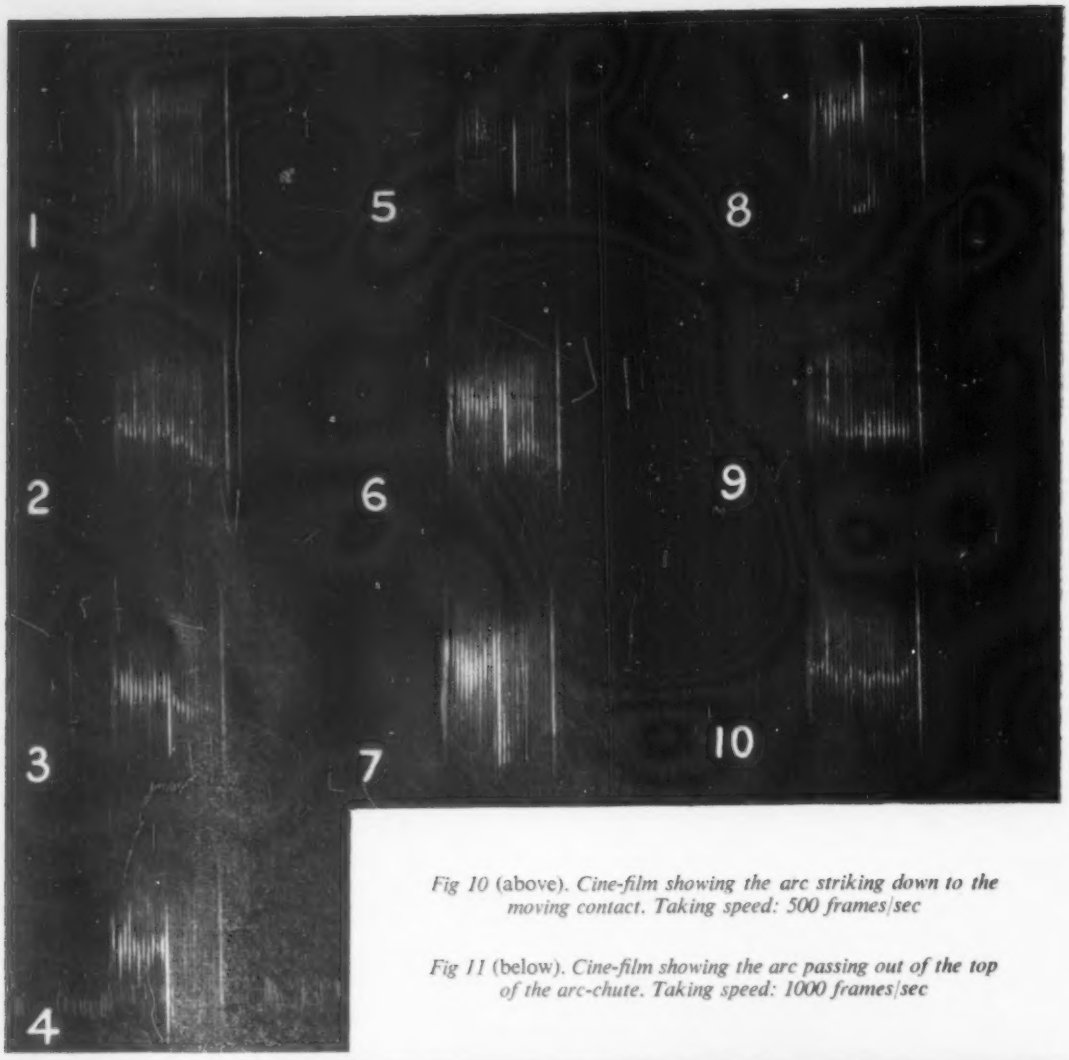
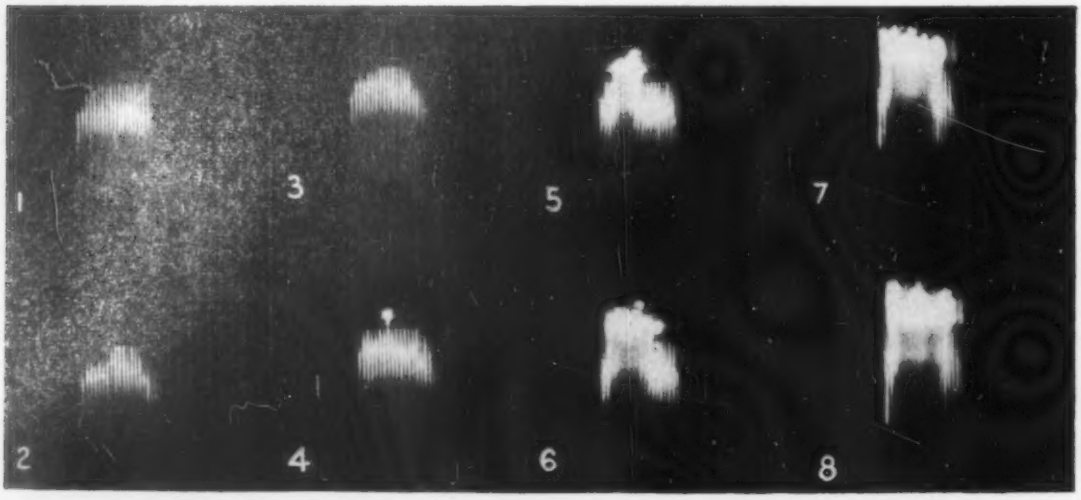
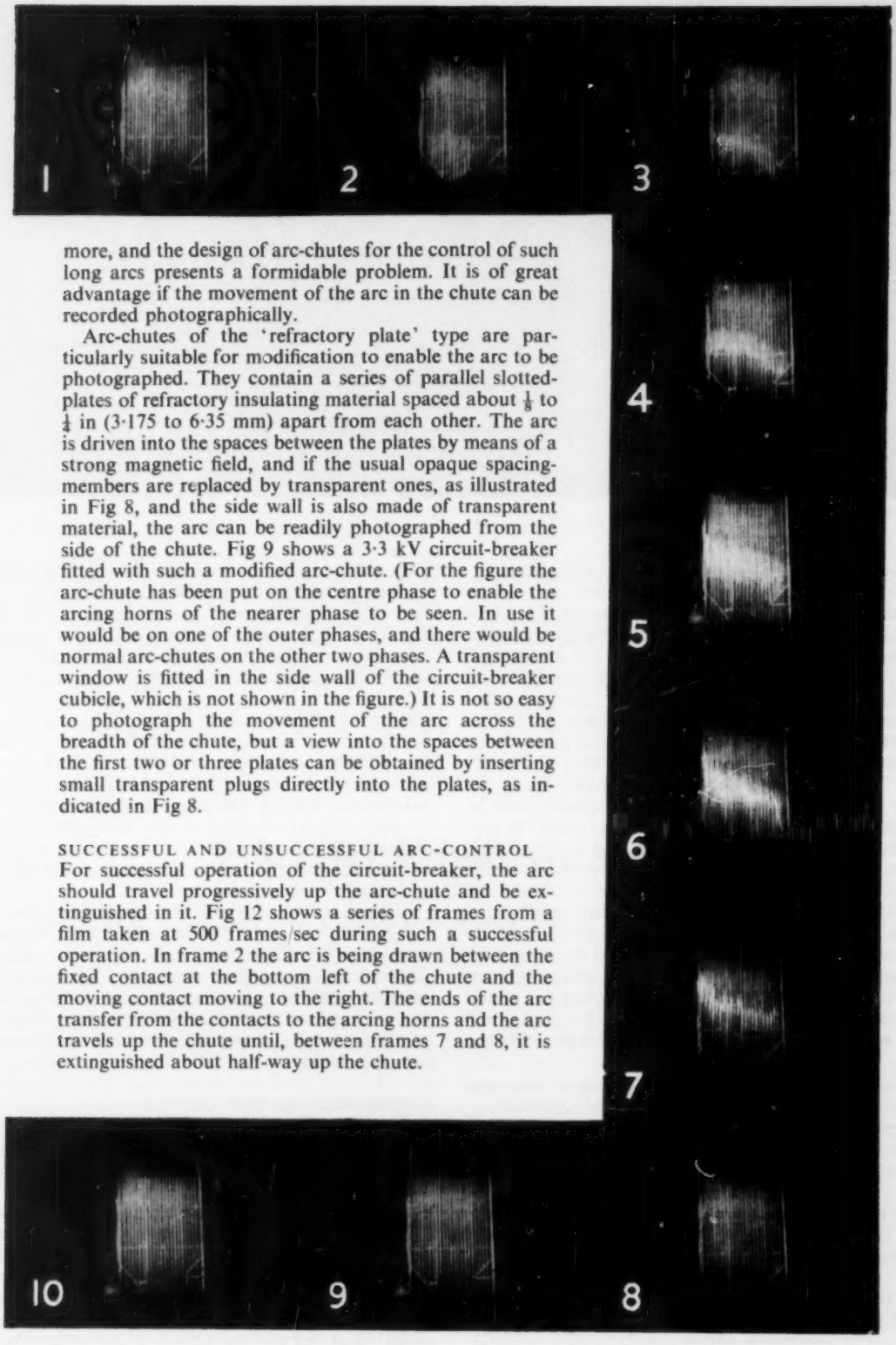


Fig 10 (above). *Cine-film showing the arc striking down to the moving contact. Taking speed: 500 frames/sec*

Fig 11 (below). *Cine-film showing the arc passing out of the top of the arc-chute. Taking speed: 1000 frames/sec*





more, and the design of arc-chutes for the control of such long arcs presents a formidable problem. It is of great advantage if the movement of the arc in the chute can be recorded photographically.

Arc-chutes of the 'refractory plate' type are particularly suitable for modification to enable the arc to be photographed. They contain a series of parallel slotted-plates of refractory insulating material spaced about $\frac{1}{8}$ to $\frac{1}{4}$ in (3·175 to 6·35 mm) apart from each other. The arc is driven into the spaces between the plates by means of a strong magnetic field, and if the usual opaque spacing-members are replaced by transparent ones, as illustrated in Fig 8, and the side wall is also made of transparent material, the arc can be readily photographed from the side of the chute. Fig 9 shows a 3·3 kV circuit-breaker fitted with such a modified arc-chute. (For the figure the arc-chute has been put on the centre phase to enable the arcing horns of the nearer phase to be seen. In use it would be on one of the outer phases, and there would be normal arc-chutes on the other two phases. A transparent window is fitted in the side wall of the circuit-breaker cubicle, which is not shown in the figure.) It is not so easy to photograph the movement of the arc across the breadth of the chute, but a view into the spaces between the first two or three plates can be obtained by inserting small transparent plugs directly into the plates, as indicated in Fig 8.

SUCCESSFUL AND UNSUCCESSFUL ARC-CONTROL

For successful operation of the circuit-breaker, the arc should travel progressively up the arc-chute and be extinguished in it. Fig 12 shows a series of frames from a film taken at 500 frames/sec during such a successful operation. In frame 2 the arc is being drawn between the fixed contact at the bottom left of the chute and the moving contact moving to the right. The ends of the arc transfer from the contacts to the arcing horns and the arc travels up the chute until, between frames 7 and 8, it is extinguished about half-way up the chute.

Fig 12. Cine-film of successful arc-extinction in an arc-chute. Taking speed: 500 frames/sec

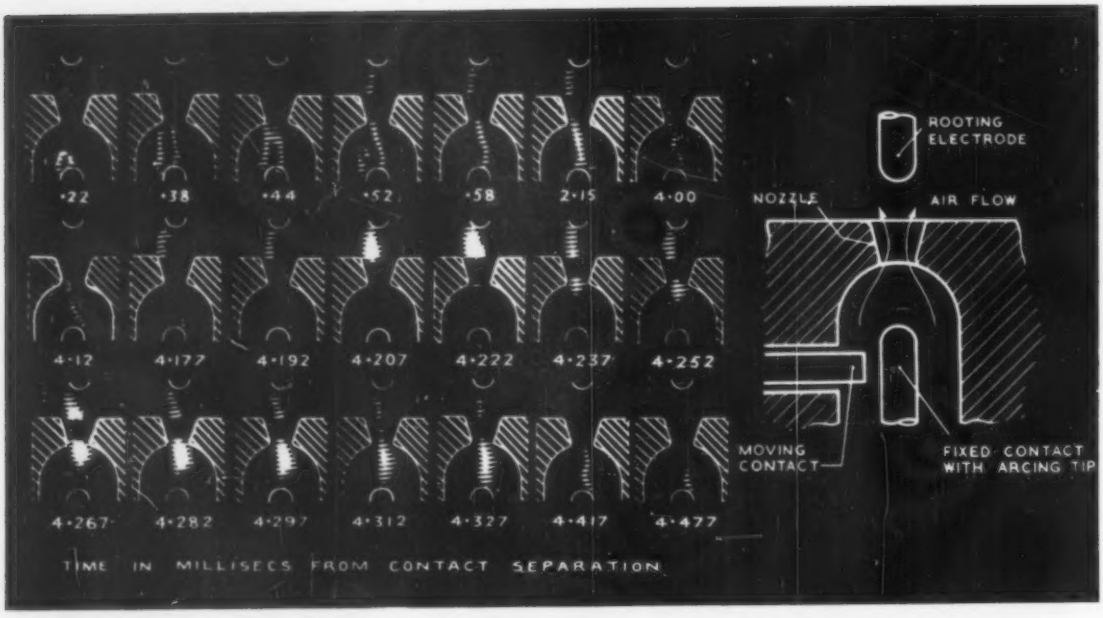


Fig 13. Pictures of the arc in an air-blast circuit-breaker obtained by means of a raster-plate cine-camera

Causes of failure or undesirably long arcing-times revealed by high-speed cine-photography include passage of the arc through the baffle or cooler at the top of the arc-chute, arcing below the arc-chute, and restriking down inside the chute and across the contacts. Fig 11 shows a series of frames from a film taken at 1000 frames/sec during the testing of an experimental arc-chute. The arc gases start to penetrate the arc-chute cooler at frame 4, the current increasingly transfers to the path so established above the cooler, and by frame 8 only about a third of the arc-chute is being effectively employed. Such transfer of the arc to a path above the arc-chute nearly always leads to failure of the circuit-breaker to clear and must be prevented by careful design of the cooler. Fig 10 shows part of a film taken at 500 frames/sec and illustrates how the arc can strike down to the moving contact. In frame 2 the arc is travelling up the chute as intended. In frame 3, however, the arc strikes vertically down from near the centre of the arc-chute to the moving contact, and by frame 4 the right-hand half of the arc-chute has been short-circuited. The vertical portion of the arc persists during the period covered by frames 3 to 7, with the result that in frame 8 the arc restrikes straight across the narrow gap between the contacts. The arc immediately rises into the chute once more, and by frame 9 has almost regained the position held during the early part of frame 3. The time lost due to the strike-down (7 frames, *i.e.* 14 ms) could not be tolerated, however, and modifications were made to the chute which prevented its occurrence.

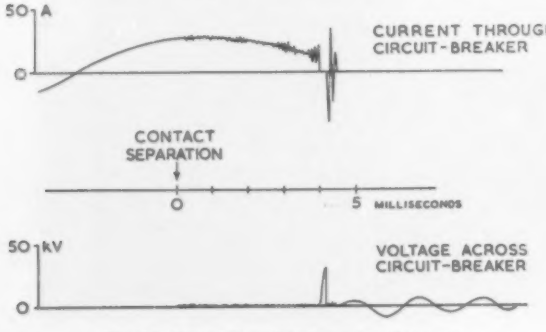


Fig 14. Current and voltage oscillograms corresponding to the cine record in Fig 13

OTHER FEATURES STUDIED

The general efficiency of an arc-chute can be improved by meticulous attention to detail, and high-speed cine-photography is of particular value in this phase of development. Among the many features that have been studied are the movement of arcs along arcing-horns, the transfer of the arc from the moving contact to the arcing-horns, pre-arcing during circuit making, and the emission of gases from the arc-chute.

High-speed cine-cameras have also been used for investigations of a more fundamental nature. For example, cathode-ray-oscillograph records of the arc voltage show fluctuations having time constants of the order of 100 microsec, and by using a camera such as that shown in Fig 3 it has been found that these fluctuations are at least partly caused by a very rapid vertical oscillation of the arc-core during its movement up the arc-chute.

Application to Air-blast Circuit-breakers

In an air-blast circuit-breaker the arc is controlled and extinguished by a high-velocity stream of air. High-speed cine-photography has been used for investigating the characteristics of the air flow and the behaviour of the arc.

Experimental circuit-breakers with plate-glass windows in the wall of the arcing chamber or with an arcing chamber made mainly of perspex have been used.

AIR FLOW

To investigate the air flow, fine flexible threads are attached at one end on surfaces of the arcing chamber or on fine supporting wires specially inserted across the path of the air stream. Such threads take up a position

generally along the flow lines of the air stream—a slight departure results from the tension in the threads, but the direction of their tips give a true indication of the direction of the flow. The threads are strongly illuminated and the camera shutter is opened just before the blast valve of the circuit-breaker is opened. From the film record it is possible to distinguish regions of stream-line flow, turbulence, and stagnation; in regions of stream-line flow the threads take up certain positions and remain steady in those positions, in regions of turbulence they are continuously moving, and in regions of stagnation they remain in their initial positions even when opposed to the prevailing direction of flow.

ARC BEHAVIOUR

It is known that in an air-blast circuit-breaker the extinction or re-ignition of the arc at a current-zero depends very largely on what happens in the neighbourhood of the arc immediately before and after the instant at which the current is zero. This crucial period may be only a fraction of a millisecond, and therefore to obtain the most useful cine records of the behaviour of the arc a camera capable of taking several hundred thousand frames/sec is used.

Fig 13 shows selected frames from a cine record of a 26-A arc being extinguished in an experimental circuit-breaker having a perspex walled arcing-chamber and a metal nozzle, and operating with air at 76 lb/sq in (5·34 kg/cm²). The camera used was of the kind illustrated in Fig 2 and the taking rate was 270,000 frames/sec. Only the arc was recorded, but on the frames shown the outlines of the fixed contact, moving contact, nozzle, and rooting electrode have been sketched in. The sequence of frames shows that soon after the arc was drawn by the withdrawal of the moving contact to the left, the air flow caused the arc to loop through the nozzle until it touched and rooted on the rooting electrode downstream of the nozzle (the arc cannot be seen in the metal nozzle).Thereafter, as shown on the frames 0·58 and 2·15 ms after contact separation, the arc continued to burn between the fixed contact and the rooting electrode until, at about 4 ms after contact separation, it was suddenly interrupted. This was before the normal 50 c/s current-zero; and, as can be seen from the corresponding current and voltage records shown in Fig 14, this sudden interruption of the current ('current-chopping') produced a high voltage between the contacts, which in turn caused the arc to re-strike between the fixed contact and the rooting electrode. The series of frames from 4·177 to 4·327 ms after contact separation shows the development of the re-struck arc. The current oscillations shown in Fig 14 are of 22 kc/s frequency, and if a very much larger number of frames than those shown in Fig 13 were printed it would be seen that these oscillations correspond to pulsations in the brightness of the arc.

POST-ARC PHENOMENA

High-speed cine-photography is also being used in combination with Schlieren techniques to study the nature of the arc path in air-blast circuit-breakers immediately after arc extinction, and it is expected that this will contribute towards a clearer understanding of the mechanism of arc extinction in such circuit-breakers, and so aid their design.

Acknowledgments

The authors are indebted to the Directors of A Reyrolle & Co Ltd for permission to publish the article; to Mr A F B Young, under whose expert guidance the work described was done; to many colleagues for their contributions, and to Mr W E Watson for editing.

Electricity tells its story

AT THE BUILDING CENTRE AND THE SCIENCE MUSEUM

ELECTRICITY has a story to tell—and two different, though related, aspects of this story are most effectively told in two notable exhibitions which are now permanently open in London. One is essentially practical and designed to appeal directly to the actual or potential user. The other is of outstanding interest to the historian, the engineer, and the student. Both portray the enterprise and the versatility of our Industry.

The Silver Jubilee Year of the Building Centre, established in 1932 and now located at Store Street, London, W1, marked the opening last year of the completely reconstructed Electrical Section which has been maintained since the inception of the Centre by the Electrical Development Association.

Although constantly changed in content to keep pace through the years with the steady development and expansion of electrical equipment and appliances, the new Electrical Section assumes an added importance and scope in keeping with the advent of the atomic age and the nuclear generation of electricity which will provide an ever-increasing proportion of the nation's supply of electrical energy.

Working from the hypothesis that the new nuclear power stations require to be kept as fully loaded as possible throughout every twenty-four hours of operation, the Electrical Section is planned and laid out to emphasize the principle that every modern building—whether agricultural, commercial, industrial, or domestic—must be fully equipped to make the greatest possible use of an abundant electricity supply. To that end, the Section is designed to help the architect, the builder, and the property owner to obtain the maximum benefit from the electricity services, and to interest the domestic occupier in making his home more comfortable and efficient.

The new Electrical Section was opened by Sir John Maud, GCB, CBE, Permanent Secretary to the Ministry of Power, with Viscount Chandos, President of the Electrical Development Association (the organizers of the Section) presiding over an audience of some 200 representatives of electrical manufacturers; the electricity supply industry;

the architectural profession; Local Government surveyors, engineers, architects and housing directors; and principals of architectural schools.

The first subject dealt with in the Section is the important one of estate and building development, and the provision at the outset of an adequate electricity supply. The growth of demand for electricity in recent years is shown by means of graphs—the domestic load has about doubled in the last ten years. Early consultation between architects and the Electricity Boards is strongly recommended and examples are given of the most economic layout of the electrical installations.

The best method of bringing the supply into the house is demonstrated and the house-wiring system explained. Here special emphasis is placed on the need for providing adequate facilities for the numerous electrical appliances the occupier of the house will inevitably wish to use. On view is a plan of a house equipped with a ring circuit, and listing the appliances it serves. These require fifty plug-points. A similar plan deals with the lighting installation, pointing out that electric lighting performs two functions in the home—illumination and decoration.

A special feature demonstrates the effects of filament and fluorescent lighting on colour and texture. Architects can bring their own materials—fabrics, wall-papers, paintwork, and so on—to test them under the different types of lighting.

Part of the exhibit is devoted to the important subject of kitchen planning, and an all-electric kitchen is included. It has fluorescent lighting and is equipped with an automatic cooker, a storage water-heater, a dish-washer, a clothes washing-machine, an ironer, a towel-airer, a refrigerator, and a fan—all in working condition. This kitchen is provided with ten plug-points. Opposite the kitchen is a display of electric cookers, and while the models exhibited will be changed periodically, the three basic types will always be represented—the 'baby' cooker for bachelor flats, the standard, and the automatic models.

The advantages of electric water-heating are presented in an attractive manner. Domestic hot water can be provided, economically and at an automatically constant temperature, precisely where it is wanted—at the kitchen sink or wash basin. The visitor to this part of the exhibit breaks a light beam and a series of five heaters each start to give half a gallon of piping hot water. Also on view are examples of hot-water systems suitable for supplying the whole house, along with models explaining how to install each type of heater.

Another method of supplying domestic hot water is by an immersion heater in conjunction with a solid fuel system. Under the heading 'Stop This Waste' comes instruction on the need for lagging the storage tank, pointing out that, with an air temperature of 60 deg F (15·6 deg C) and water at 140 deg F (60 deg C) heat losses from an unlagged 30 gallon (136 l) tank in continuous operation would be equivalent to a wastage of over 17,000 gallons (77,000 l) of hot water in a year.

In the home-laundry section are displayed all types of electric washing appliances—from the wash-boiler to the fully automatic machine which washes, rinses, and dries the clothes in readiness for ironing. Among the other appliances on view are spin-driers, tumbler-driers, a sit-down ironer, and a drop-down ironing-board with a plug-point inside the cupboard so placed that the flex is kept clear of the board when the iron is in use.

In the refrigeration section is a range of electric refrigerators, with the accent on the larger model. Also on show is an electric home-freezer which not only stores the many varieties of frozen foods now available, but enables home-grown produce to be stored when at its best and eaten when desired.

Electricity for home heating is deservedly popular, economical, and safe. Increasing numbers of local authorities throughout the country are providing all-electric houses and flats which incorporate electric floor warming—the system used to heat the Electrical Section of the Building Centre. Two different types of withdrawable systems are employed and these can be studied through two glass inspection panels situated near the entrance and in the industrial department. In the heating section every type of electric space-heater can be seen —radiant fires, radiant panels, convectors, tubular heaters, and oil-filled radiators.

Allied to heating is the question of thermal insulation. Sectional models of various parts of a house show how heat losses can be avoided.

In the commercial and industrial section, attention is drawn to the advantages to be derived from off-peak thermal storage heating. In addition to floor warming, there is the thermal block storage-heater which is particularly suitable for existing buildings. This heater only uses electricity overnight, is controlled by time switch and thermostat, and gives out its stored heat during the day. The other feature in this part of the exhibit is a selection of electric catering equipment. Recent regulations regarding hygiene in catering establishments support the case for the use of electricity; electric kitchens are cleaner, cooler, and pleasanter places in which to work. Also exhibited are electrical equipments for air-conditioning and an electric hand-dryer which does away with the need for towels.

An expert information service and supplies of all relevant literature are available to all visitors on request.

The new electric power collection at the Science Museum, South Kensington, which was recently reviewed in this Journal,* portrays the birth and development of the industry from the discoveries of the nineteenth-century philosophers to the present-day application of nuclear power. The story is told in a series of dioramas, models, and panel displays, but it also includes many items of equipment both old and new, among the former being the original turboalternator of Sir Charles Parsons of 1900, and among the latter a one million volt impulse generator which is demonstrated to visitors twice daily.

* THE BEAMA JOURNAL, August 1957, p. 118.

A Correction

We regret that, despite careful checking, an error occurred in the article entitled 'Space Heating by Electricity' in the November 1957 issue. The sentence at the end of the first paragraph in the second column on page 163 should be amended to read: In the last few years the installation of electrode-boiler space-heating installations has provided an off-peak load of some 15,000 kW.

The electrolytic tank analogue

K F Sander, PhD, AMIEE*

Introduction

THE electrolytic tank analogue, which has been coming into vogue during recent years, is in fact relatively old in origin, the analogue having been pointed out by both Kirchhoff and Maxwell. More recently attention was drawn to it by Fortescue and Farnsworth in 1913.[1] It suffers from the disadvantage of most analogue devices: a deceptive simplicity which enables an accuracy of few per cent to be obtained easily, but is in reality a complicated structure requiring considerable research and development before a reliable device is produced.

The tank analogue itself is based on the fact that current flow in a homogeneous isotropic conducting medium is described by a potential function satisfying Laplace's equation. Hence any physical phenomenon which can be similarly described has an analogue with this current flow. The only suitable conducting medium available is water, with additions to give appropriate conductivity, and hence the name 'electrolytic tank'.

A great amount of work has been done since the war, and, in particular, workers at Cambridge University Engineering Laboratory, with the support of the Admiralty, have been developing tanks since 1947 for use as part of a larger equipment. It is in fact an ideal problem for University research. Most of the other workers have wanted a tank for the solution of a particular problem in a short time, and under such circumstances annoying details have to be circumvented rather than time spent on understanding them. However, only when all such details are understood can a truly reliable instrument be made. The aim at Cambridge has been to produce such an instrument capable of giving information on field gradients to an accuracy of 0·1 per cent.

* Department of Engineering, University of Cambridge.

A Basic System

In order to fix ideas, it is of advantage to consider the application of the analogue to a particular problem. Problems in electrostatics are of frequent occurrence and provide the most straightforward example of the use of the tank. In this application the only difference between the analogue and the actual problem, apart from scale, is that in the analogue current will flow between the electrodes, whereas negligible current will flow on the application of steady pd's to electrodes separated by an insulator. Examples of practical interest may be found in both heavy and light electrical engineering. In the former, the problem of determining the field near the lead-out from a high-voltage transformer may be considered, and in the latter, the electrostatic field in a radio valve.

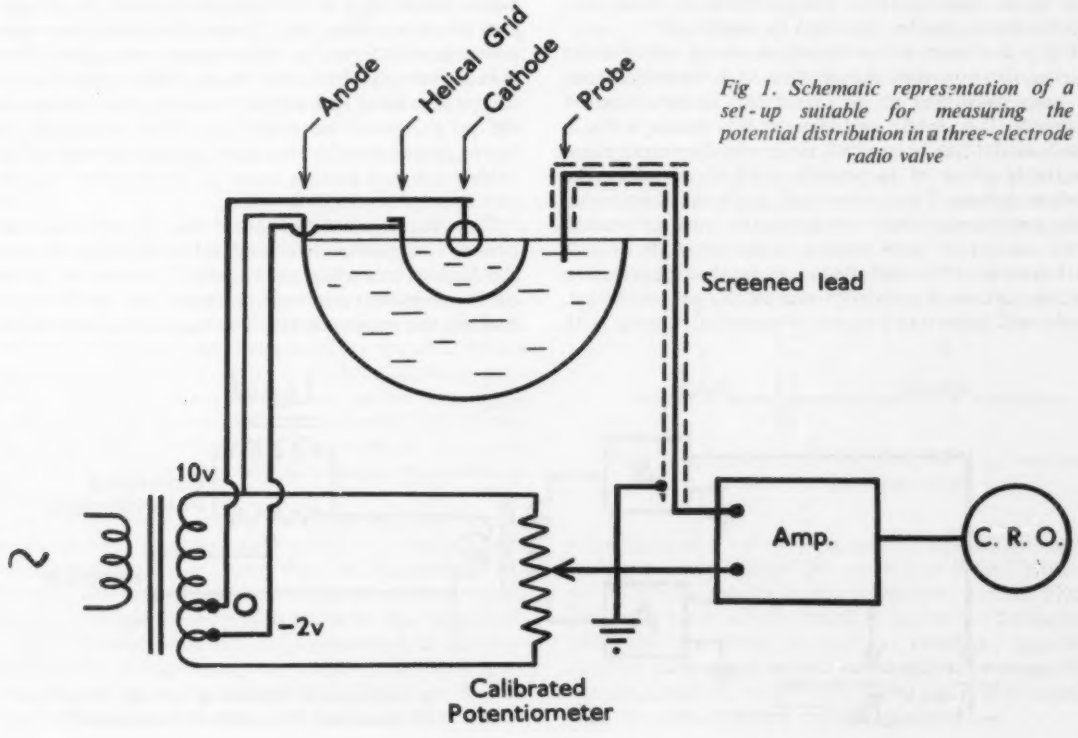


Fig 1. Schematic representation of a set-up suitable for measuring the potential distribution in a three-electrode radio valve

Although it is possible to conceive an electrolytic tank analogue of an arbitrary three-dimensional problem, it is of much greater simplicity and use to consider those problems involving structures which have a plane of symmetry which no field lines cross. When such a plane is present, a system consisting of the structure to one side of the plane will give fields identical with those in the complete structure, providing the absent side is replaced by a semi-infinite medium at the surface of which no normal field can be sustained. In the electrostatic case this corresponds to infinite dielectric constant and is therefore impracticable, but in the analogue it corresponds to a non-conductor. Hence the practice is to make a model of the structures and place it in a bath of conducting liquid, so that the free surface of the liquid is the plane of symmetry of the structure. The field in the liquid will then be

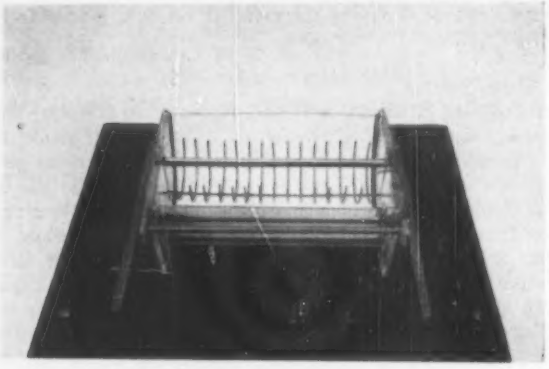


Fig 2. A photograph of the actual model used with the set-up indicated in Fig 1

that of the complete model, but the free surface is available to insert small probes. The potential of these with respect to the electrodes can then be measured.

In Fig 1 is shown schematically a set-up suitable for measuring the potential distribution in a three-electrode radio valve, assumed to be cylindrical in structure. A photograph of the model and apparatus is shown in Fig 2.

A half-model has been used, since any diametral plane is a suitable plane of symmetry in which to make the electrolyte surface. The probe itself might be of platinum or other corrosion-resistive material, and must be located by some mechanism with respect to the electrode boundaries. It must also be controlled in its depth of penetration below the surface. Considered electrically as a terminal, the probe will behave as a source of potential in series with an impedance. The magnitude of the potential will be the average potential of the region occupied by the probe, and the impedance will depend on the probe dimensions and material, and the electrolyte. It may be in the region 10 kΩ-500 kΩ. It is therefore necessary to make the measurement of the probe potential by a potentiometer method, in which no current is drawn from the probe at the balance point. If current is drawn the measured potential will be in error.

The model has been shown supplied with an alternating voltage. It is necessary to use ac, for with dc polarization effects and possibly electrolysis would take place. 50 c/s can be used for simple potential measurements, but higher frequencies, about 1 kc/s, are most suitable for general application. The use of ac simplifies the choice of detector, since the cathode-ray oscilloscope and amplifier provides a simple, robust, and highly sensitive indicator of high input impedance which is required to register only a null value. In the circuit shown the actual measuring instrument is the potentiometer. When this is adjusted for zero pd across the detector, no current can be drawn from the probe, and the pd of the probe with respect to any electrode can be calculated from the position of the slider. A commercial wire-wound potentiometer of some 3 in (76 mm) diameter and several thousand ohms impedance can easily be calibrated to give 0·5 per cent accuracy of potential measurement.

The position of the earth connexion is of some importance. By earthing the slider of the potentiometer as shown, in the balanced condition any stray capacities from the probe to earth produce no effect. Since the probe is usually the highest impedance point in the circuit it is most sensitive to such strays.

If it is required to measure field gradients, this can be done in principle by measuring potential at two neighbouring points. However, such a procedure requires accurate knowledge of the distance between the two points and involves taking the difference between two values of potential which may be large compared to that difference. It is far better to make the measurement directly by using two probes fixed with respect to each other and measuring the pd produced between them. This will easily give a figure proportional to the field gradient at any point, and calibration in a known model is the simplest way to convert this to an absolute value.

The direct measurement of the pd between the two probes is a matter of considerable difficulty if results of the highest accuracy are required. Neither is at exactly earth potential, and current must not be drawn when making the measurement. The methods of making such a

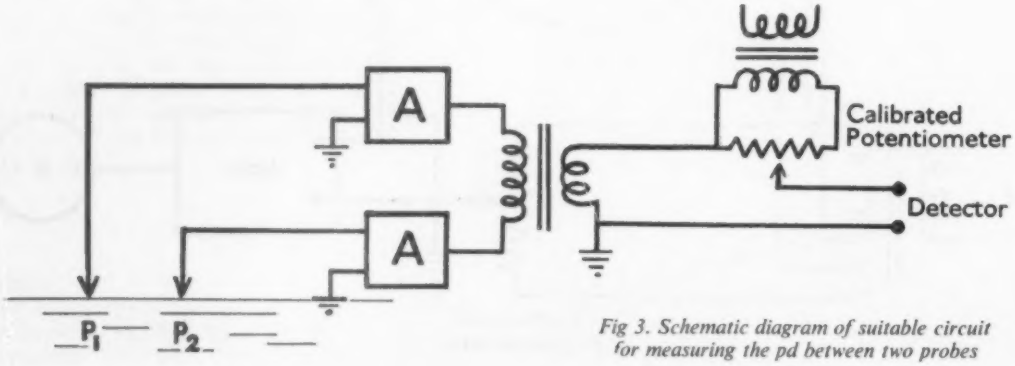


Fig 3. Schematic diagram of suitable circuit for measuring the pd between two probes

measurement depend on the accuracy required, but it is almost always essential to use an electronic valve device to isolate the probe from the measuring circuit. A schematic circuit is shown in Fig 3. *A* is a valve device, such as a cathode-follower which presents a high impedance to the probe and hence draws negligible current, and reproduces the pd between input and earth at the output. A transformer can be used to take the difference between these potentials and transfer it to a secondary winding, one side of which is earthed. A variable source in series with this winding can be adjusted to provide a null signal at a detector and hence to measure the pd between the probes. Since the devices *A* must operate with input between probe and earth, it is desirable to retain the feature of the circuit of Fig 1 which enables the potential of the probes to be reduced to about earth potential. If

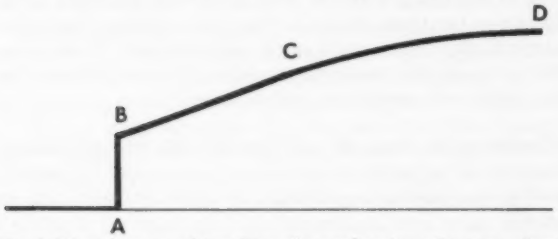


Fig 4. Waveform resulting from the application of a step voltage across a mass of electrolyte through plane electrodes

this is not done errors may be introduced by stray capacities or by slight inequalities of gain of the two devices *A*.

It will be appreciated that since the voltages are alternating, phase shifts can occur at various points in the circuits, and can also be produced by the polarization effects at the electrode-electrolyte interfaces. Hence the process of taking differences is rarely exact unless a variable phase shift can be provided. Difficulties arising from this source are not usually troublesome in potential measurements, but can easily cause great difficulties in field gradient measurements. In such measurements it may be required to measure to 0·1 per cent a pd having a value of a tenth of the pd applied across the tank. Hence signals of 10^{-5} of the total tank voltage may assume importance.

Errors

Having described the equipment required to make tank measurements, it is necessary to consider the sources of error which are present. These may be divided into classes. There are, first, instrumental errors resulting from unsatisfactory measuring methods. These have virtually been considered in the previous paragraphs by the description of apparatus designed, for example, to avoid drawing current from the probe. Another difficulty of the same type concerns the actual manufacture of the model, which may deviate from that for which results are wanted. This class of error can in principle be reduced as much as desired by attention to detail.

Second, there are what may be called inherent errors: those which make the analogue inexact. It is these which are of prime importance, since they set the limit of accuracy possible. One of the chief nuisances in electrolytic tank work is polarization, which concerns the behaviour of an ionic conductor in the neighbourhood of an electrode boundary. Major errors can result from the type of probe used; any object placed in the field region will produce perturbing effects on that field, and hence the meaning of results with multi-probe arrays have to be carefully considered.

Other effects, unavoidable when a free surface is used as the measuring plane, are the meniscii at probes and electrodes; these are essentially variable, depending on temperature and cleanliness of the surface. The purely mechanical problem of keeping the probe at constant depth below the surface is primarily instrumental, but is intimately bound up with the type of probe used, since the rate of change of pd between two adjacent probes with depth is very dependent on probe construction. A further source of error at the highest accuracy is the inhomogeneity of the electrolyte due to temperature variations.

The polarization effects and the effects present in multi-probe arrays will now be considered in more detail.

Polarization

The conduction mechanism in an electrolyte is the movement of ions under the applied fields. At the frequencies used in tank work the bulk impedance of a weak electrolyte is almost wholly resistive, but at boundaries certain effects occur. These are best illustrated by considering the application of a step-voltage across a mass of electrolyte through plane electrodes.

It is possible to determine[2] the pd between the actual electrode and a surface very close to it but in the electrolyte. It is found that this pd is of the form shown in Fig 4. A sudden step occurs at switching on, followed by a steady rise which is linear in the early stages (in the range *BC*), corresponding to times up to several milliseconds. The equivalent circuit giving the same behaviour is shown in Fig 5. The boundary effect is represented by resistance *r* in series with capacity *C*, and the bulk electrolyte by the large resistance *R*. This is valid only for frequencies of period lying in the linear range in Fig 4. At lower frequencies the boundary effect will require a more complicated equivalent circuit. Measurements show that the step *AB* is of the same order of magnitude for most practical combinations and is virtually independent of conductivity of the electrolyte for a constant applied voltage. The slope, however, is proportional to conductivity, and varies greatly with materials and the state of the surface. In terms of the equivalent circuit, this implies that for a given electrolyte, both *r* and *R* decrease with increase of concentration, but that *C* remains constant. Hence the step *AB* may be regarded as equivalent to a definite thickness of electrolyte.

The errors introduced by this effect depend on the applied voltage waveform. If a sine wave is used, the total

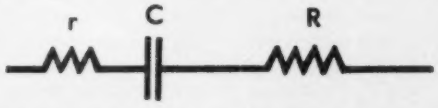


Fig 5. Equivalent circuit producing the same behaviour as the waveform shown in Fig 4

impedance of $r + R$ in series with *C* will be relevant, producing a phase shift of the current in *R* and hence in the pd between a probe in the electrolyte and an electrode. The least error which occurs is equivalent to moving the electrode back from its physical position, regarding the resistance *r* in terms of extra electrolyte. The magnitude of the displacement varies with materials, but is usually less than 0·1 mm, which is rarely significant.

Although it is possible to conceive an electrolytic tank analogue of an arbitrary three-dimensional problem, it is of much greater simplicity and use to consider those problems involving structures which have a plane of symmetry which no field lines cross. When such a plane is present, a system consisting of the structure to one side of the plane will give fields identical with those in the complete structure, providing the absent side is replaced by a semi-infinite medium at the surface of which no normal field can be sustained. In the electrostatic case this corresponds to infinite dielectric constant and is therefore impracticable, but in the analogue it corresponds to a non-conductor. Hence the practice is to make a model of the structures and place it in a bath of conducting liquid, so that the free surface of the liquid is the plane of symmetry of the structure. The field in the liquid will then be

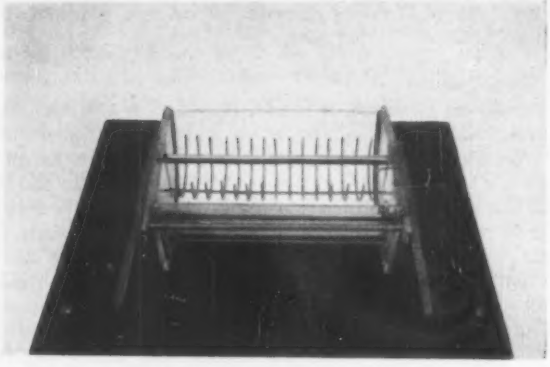


Fig 2. A photograph of the actual model used with the set-up indicated in Fig 1

that of the complete model, but the free surface is available to insert small probes. The potential of these with respect to the electrodes can then be measured.

In Fig 1 is shown schematically a set-up suitable for measuring the potential distribution in a three-electrode radio valve, assumed to be cylindrical in structure. A photograph of the model and apparatus is shown in Fig 2.

A half-model has been used, since any diametral plane is a suitable plane of symmetry in which to make the electrolyte surface. The probe itself might be of platinum or other corrosion-resistive material, and must be located by some mechanism with respect to the electrode boundaries. It must also be controlled in its depth of penetration below the surface. Considered electrically as a terminal, the probe will behave as a source of potential in series with an impedance. The magnitude of the potential will be the average potential of the region occupied by the probe, and the impedance will depend on the probe dimensions and material, and the electrolyte. It may be in the region 10 kΩ-500 kΩ. It is therefore necessary to make the measurement of the probe potential by a potentiometer method, in which no current is drawn from the probe at the balance point. If current is drawn the measured potential will be in error.

The model has been shown supplied with an alternating voltage. It is necessary to use ac, for with dc polarization effects and possibly electrolysis would take place. 50 c/s can be used for simple potential measurements, but higher frequencies, about 1 kc/s, are most suitable for general application. The use of ac simplifies the choice of detector, since the cathode-ray oscilloscope and amplifier provides a simple, robust, and highly sensitive indicator of high input impedance which is required to register only a null value. In the circuit shown the actual measuring instrument is the potentiometer. When this is adjusted for zero pd across the detector, no current can be drawn from the probe, and the pd of the probe with respect to any electrode can be calculated from the position of the slider. A commercial wire-wound potentiometer of some 3 in (76 mm) diameter and several thousand ohms impedance can easily be calibrated to give 0·5 per cent accuracy of potential measurement.

The position of the earth connexion is of some importance. By earthing the slider of the potentiometer as shown, in the balanced condition any stray capacities from the probe to earth produce no effect. Since the probe is usually the highest impedance point in the circuit it is most sensitive to such strays.

If it is required to measure field gradients, this can be done in principle by measuring potential at two neighbouring points. However, such a procedure requires accurate knowledge of the distance between the two points and involves taking the difference between two values of potential which may be large compared to that difference. It is far better to make the measurement directly by using two probes fixed with respect to each other and measuring the pd produced between them. This will easily give a figure proportional to the field gradient at any point, and calibration in a known model is the simplest way to convert this to an absolute value.

The direct measurement of the pd between the two probes is a matter of considerable difficulty if results of the highest accuracy are required. Neither is at exactly earth potential, and current must not be drawn when making the measurement. The methods of making such a

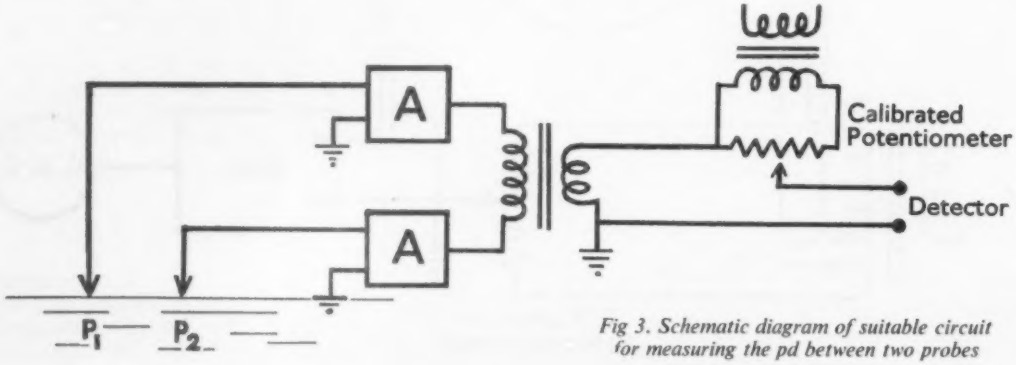


Fig 3. Schematic diagram of suitable circuit for measuring the pd between two probes

measurement depend on the accuracy required, but it is almost always essential to use an electronic valve device to isolate the probe from the measuring circuit. A schematic circuit is shown in Fig 3. *A* is a valve device, such as a cathode-follower which presents a high impedance to the probe and hence draws negligible current, and reproduces the pd between input and earth at the output. A transformer can be used to take the difference between these potentials and transfer it to a secondary winding, one side of which is earthed. A variable source in series with this winding can be adjusted to provide a null signal at a detector and hence to measure the pd between the probes. Since the devices *A* must operate with input between probe and earth, it is desirable to retain the feature of the circuit of Fig 1 which enables the potential of the probes to be reduced to about earth potential. If

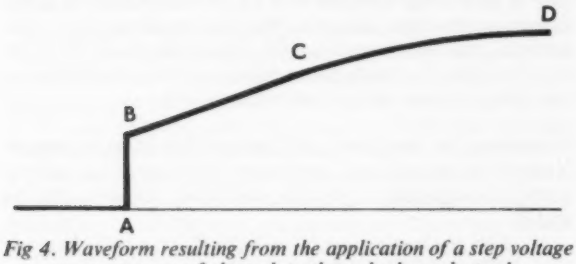


Fig 4. Waveform resulting from the application of a step voltage across a mass of electrolyte through plane electrodes

this is not done errors may be introduced by stray capacities or by slight inequalities of gain of the two devices *A*.

It will be appreciated that since the voltages are alternating, phase shifts can occur at various points in the circuits, and can also be produced by the polarization effects at the electrode-electrolyte interfaces. Hence the process of taking differences is rarely exact unless a variable phase shift can be provided. Difficulties arising from this source are not usually troublesome in potential measurements, but can easily cause great difficulties in field gradient measurements. In such measurements it may be required to measure to 0·1 per cent a pd having a value of a tenth of the pd applied across the tank. Hence signals of 10^{-5} of the total tank voltage may assume importance.

Errors

Having described the equipment required to make tank measurements, it is necessary to consider the sources of error which are present. These may be divided into classes. There are, first, instrumental errors resulting from unsatisfactory measuring methods. These have virtually been considered in the previous paragraphs by the description of apparatus designed, for example, to avoid drawing current from the probe. Another difficulty of the same type concerns the actual manufacture of the model, which may deviate from that for which results are wanted. This class of error can in principle be reduced as much as desired by attention to detail.

Second, there are what may be called inherent errors: those which make the analogue inexact. It is these which are of prime importance, since they set the limit of accuracy possible. One of the chief nuisances in electrolytic tank work is polarization, which concerns the behaviour of an ionic conductor in the neighbourhood of an electrode boundary. Major errors can result from the type of probe used; any object placed in the field region will produce perturbing effects on that field, and hence the meaning of results with multi-probe arrays have to be carefully considered.

Other effects, unavoidable when a free surface is used as the measuring plane, are the meniscii at probes and electrodes; these are essentially variable, depending on temperature and cleanliness of the surface. The purely mechanical problem of keeping the probe at constant depth below the surface is primarily instrumental, but is intimately bound up with the type of probe used, since the rate of change of pd between two adjacent probes with depth is very dependent on probe construction. A further source of error at the highest accuracy is the inhomogeneity of the electrolyte due to temperature variations.

The polarization effects and the effects present in multi-probe arrays will now be considered in more detail.

Polarization

The conduction mechanism in an electrolyte is the movement of ions under the applied fields. At the frequencies used in tank work the bulk impedance of a weak electrolyte is almost wholly resistive, but at boundaries certain effects occur. These are best illustrated by considering the application of a step-voltage across a mass of electrolyte through plane electrodes.

It is possible to determine[2] the pd between the actual electrode and a surface very close to it but in the electrolyte. It is found that this pd is of the form shown in Fig 4. A sudden step occurs at switching on, followed by a steady rise which is linear in the early stages (in the range *BC*), corresponding to times up to several milliseconds. The equivalent circuit giving the same behaviour is shown in Fig 5. The boundary effect is represented by resistance *r* in series with capacity *C*, and the bulk electrolyte by the large resistance *R*. This is valid only for frequencies of period lying in the linear range in Fig 4. At lower frequencies the boundary effect will require a more complicated equivalent circuit. Measurements show that the step *AB* is of the same order of magnitude for most practical combinations and is virtually independent of conductivity of the electrolyte for a constant applied voltage. The slope, however, is proportional to conductivity, and varies greatly with materials and the state of the surface. In terms of the equivalent circuit, this implies that for a given electrolyte, both *r* and *R* decrease with increase of concentration, but that *C* remains constant. Hence the step *AB* may be regarded as equivalent to a definite thickness of electrolyte.

The errors introduced by this effect depend on the applied voltage waveform. If a sine wave is used, the total

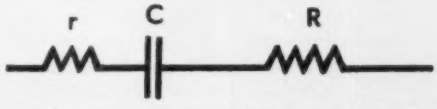


Fig 5. Equivalent circuit producing the same behaviour as the waveform shown in Fig 4

impedance of $r + R$ in series with *C* will be relevant, producing a phase shift of the current in *R* and hence in the pd between a probe in the electrolyte and an electrode. The least error which occurs is equivalent to moving the electrode back from its physical position, regarding the resistance *r* in terms of extra electrolyte. The magnitude of the displacement varies with materials, but is usually less than 0·1 mm, which is rarely significant.

If a square waveform of voltage is used, this least error can be easily realized. The voltage between electrode and a point in the electrolyte will be as shown in Fig 6. The height AB will correspond to the change in applied voltage less the initial drop across the electrode-electrolyte boundary. The slope BC is due to the build-up of voltage across that boundary layer. If the slopes are linear the vertical distance between P and Q, the unit points of successive half-cycles, is equal to AB. This latter distance can be measured easily, much more so than the distance AB, and the result is independent of the slope BC. Since this slope is highly variable, independence of its exact value is highly desirable.

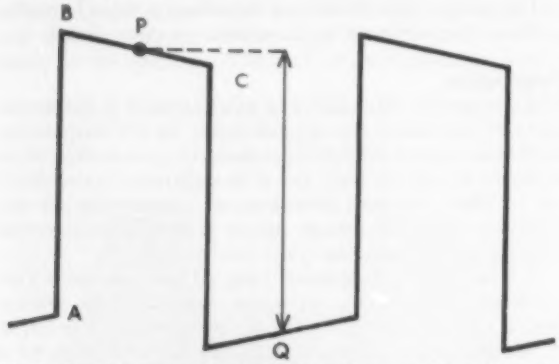


Fig 6. Resulting waveform of voltage between electrode and a point in the electrolyte when a square-wave voltage is applied

With sine-wave excitation the variable phase shift can be of considerable nuisance. The reason for the difficulty in measuring the height AB directly is that stray capacities will have the effect of rounding off this edge, and if it is compared with the original square wave by a potentiometer method a waveform of the type shown in Fig 7 will result. Large spikes appear at every change-over, decaying away rapidly. Providing the period is not too short, the slope settles down and the difference waveform shown is easily adjusted so that the slopes extrapolated backwards intersect the end point of the previous half-cycle.

Effects with Multi-probe Arrays

The measurement of potential distribution to 0·5 per cent is relatively easy. The direct measurement of gradients requires the use of at least two probes, and if complete information relative to Cartesian axes is wanted, then four probes are desirable. These must be closely spaced if the pd between them is to be proportional to field gradient. The net result of such an array is to produce a large meniscus, raising the average height of electrolyte between the probes above the undisturbed surface. The result of this is evidently to reduce the field gradient below that in the undisturbed liquid. Provided the probes are well away from a boundary, the reduction will be a proportional one, but nevertheless varying if the meniscus varies. This state of affairs makes for inconsistency in readings.

In addition to meniscus effects, the probes themselves produce electrical perturbations. A single probe well away from a boundary will measure average potential over the region it occupies, although it produces its own perturbing field in its immediate neighbourhood. A second probe, placed near the first one in the region where the perturbing field is significant, will take up a potential which depends on the first probe as well as the position relative to the electrodes. Again the effect is a linear one, in that the measured pd between the probes is proportional to field gradient but not equal to that field gradient multiplied by the distance separating the probes. This is usually of little importance since the probes will be calibrated electrically, but may assume great importance in the neighbourhood of boundaries.

The type of probe usually used has been platinum wire mounted in some suitable fashion. Evidently the perturbations produced by such a wire will depend on the depth of penetration. To get reproducibility to 0·1 per cent, the depth of penetration usually has to be held constant to within 0·1 mm. This means that evaporation must be allowed for, as well as the effects of ripples on the surface.

A type of probe which has found application is the capillary probe.[2] This is essentially a thin-walled capillary of insulating material with an internal electrode withdrawn at least one diameter from the opening. The great merit is that the current in the electrolyte does not then flow through the conductor, and thus reduces its perturbation field and associated polarisation effects.

Conditions for Accurate and Reproducible Measurements

Regarding the tank as a measuring instrument for solving particular problems, several desirable features can be stated.

(1) The analogue must be sufficiently true to be capable of providing a solution to the required accuracy.
(2) The device as a whole should provide consistent readings, both over long and short terms; the same model inserted a second time six months later should give exactly the same readings as on the first occasion.
(3) Results should not depend critically on factors which are difficult to control: *e.g.* temperature and cleanliness of the electrodes.

The factors affecting (1) are model-making accuracy and polarization effects. The errors introduced by the latter are usually less than those introduced by the former. Additional factors occur which, strictly speaking, are controllable but practically may be difficult to control. One of these is the effect of tank walls; the model includes every conductor or insulator in the region of non-zero

Fig 7. Comparing the original square-wave voltage with the resultant waveform of Fig 6 by a potentiometer method produces this waveform

field gradient. The relevance of this factor depends on the particular model and the size of the tank. The accuracy with which the probes read field gradient are considered to fall in category (2).

The factors affecting category (2) include mechanical

positioning of the model, which should be kinematically mounted on a sufficiently rigid frame to ensure replacement in the same position. Similarly the probe position and depth, and the height of the liquid surface, must be controlled. These present problems which are straightforward to solve. The more difficult problems are posed by the behaviour of the probes. The essential requirement is that the constant of proportionality relating pd between them to the field gradient shall be known and be constant. Mechanical problems of rigidity and depth of penetration exist, but the one of over-riding importance is the meniscus, which is virtually uncontrollable with the type of free surface attainable in laboratory conditions. The only fundamental improvement possible is the elimination of the free surface by a controlled interface with an insulator other than air. A way of doing this is described below.

In category (3) temperature inhomogeneities can be reduced by adequate circulation. At room temperature the temperature coefficient of resistance of a weak aqueous electrolyte is several per cent per degree C. For results of 0·1 per cent accuracy this implies tolerable average temperature differences of the order of 0·05 deg C.

The cleanliness of model electrodes depends in the first place on the material of which they are made and the electrolyte in which they are immersed. The other factor determining the choice of these materials is the polarization behaviour, which has been considered above. Whether sine-wave or square-wave excitation is used, it is desirable to reduce the capacitative drop across the boundary layer as much as possible in comparison with that across the bulk electrolyte. This can be done by reducing the electrolyte conductivity. This process cannot be carried too far or the impedance of the probes may become too high for easy handling by the electrical circuits. A figure of 10^{-4} mho/cm may be regarded as typical. Tap-water suitably treated is very satisfactory. With such an electrolyte metals such as brass tarnish very easily, and this in turn produces an increase in the capacitative drop. Non-tarnishable metals, such as stainless steel, have obvious attractions, but the possibility of their use depends on the system of excitation used. It is found that with sine waves the phase shifts produced with stainless steel are intolerable. With square waves, however, there is a far greater margin in hand since the linear slope does not directly affect the measurements, and with this technique stainless steel is ideal.

Work at Cambridge extending over a number of years has indicated that far less trouble is experienced with a system using the square-wave technique and stainless steel electrodes than is apparent from many reports by workers using sine waves. With the latter it appears necessary for the best results to make elaborate electrode preparations, such as brass etched and coated with colloidal graphite.

A System for Measuring Field Gradients to 0·1 per cent

It is evident from the above considerations that, apart from satisfactory mechanical design, the chief problems are elimination of meniscus variations and correct design of probes. A tank capable of giving consistent and

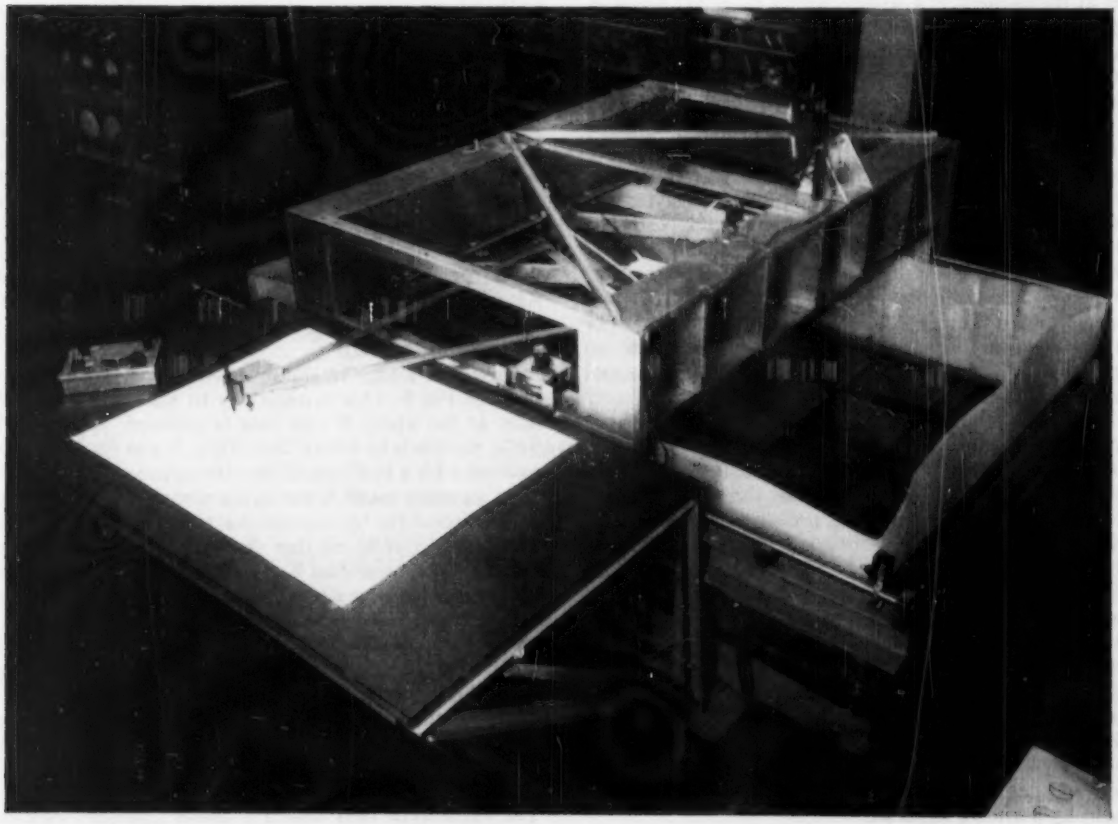


Fig 8. The tank evolved at Cambridge and fully described in the text. It is capable of consistent and accurate results to 0·1 per cent

accurate values to 0·1 per cent has been evolved at Cambridge during the last few years by the late J G Yates, the author, and their co-workers, and this will now be described.[3]

The square-wave technique outlined above has been used at frequencies between 1 and 2 kc/s. The circuitry for measuring the pd between probes has been fully described in the literature.[2]

The meniscus problem has been solved by causing the plane of measurement to be determined by a plane sheet of glass, so eliminating the free surface completely. For convenience of manufacture the more usual arrangement has been inverted, and the bottom of the tank is made of $\frac{1}{4}$ in (6·35 mm) plate-glass held flat to less than $\pm$0·005 in (0·127 mm) under all possible loading conditions. This is accomplished by supporting it at points on a 9 in (228·6 mm) square mesh which are adjustable in height with respect to a rigid steel frame. The dimensions of the biggest tank yet constructed are 6 ft by 4 ft by 1 ft 3 in (183 by 122 by 38 cm) deep. When full this holds approximately 15 cwt (760 kg) of water.

The probe assembly is fixed relative to the tank bottom, and the model is supported on a carriage which can be adjusted in position in two mutually perpendicular directions corresponding to Cartesian axes. Each probe is formed by a hole about 0·5 mm in diameter opening out into a larger hole as rapidly as can be achieved by the available mechanical means. In the larger cavity is a platinum wire electrode. There is thus formed a capillary probe with the capillary 0·5 mm in diameter and between 0·1 and 0·2 mm long. The array is formed by four of these holes at the corners of a square with a diagonal 5 mm in length. For ease of construction this array is made in a perspex rod which is let into a hole in the glass through a water-tight seal. The top of the rod is flush with the glass to an accuracy of about 0·001 in. In use the holes and associated cavities are filled with electrolyte, when the resistance of each is about 150 kΩ. These probes have great advantages over any other type: they are unbreakable, since nothing protrudes into the electrolyte; the initial calibration remains good indefinitely; the perturbation produced by each is much less than that from any conductor or insulator inserted in the liquid. Measurements show that for a four-probe array, with holes 1 mm diameter and 6 mm apart, the effective spacing is 1 per cent less than the distance between centres. Meniscii no longer exist, and the instability associated with the normal type of tank disappears.

Mechanical Details

With a tank of this type the difficulties are primarily mechanical. The method of supporting the glass has been indicated, but there remains the problem of moving the model, holding it to a prescribed height above the flat bottom to within a tolerance of a few thousandths of an inch. This is accomplished by means of two straight parallel runners along the length of the tank, supported against the loading applied, together with a further pair at right angles to the first mounted on a rigid carriage. The model is then mounted kinematically from a cross carriage. The kinematic mount on the model frame consists of three balls working respectively in a hole, a V-groove, and on a plane. The balls are mounted on micrometer heads, so that the model can be raised clear from the bottom by a known distance.

The manner of aligning the glass bottom is worthy of comment. The first step is to align one longitudinal runner against a straight edge, using feeler gauges. The second is to adjust one end-support of the other longitudinal runner until the four end-supports are co-planar. This is done by supporting a rigid bar at the ends of a diagonal and measuring the height of the centre above the base with a dial gauge. The bar is then placed on the other diagonal and, using the same three points, an end-support adjusted until the centre height is the same. The ends of the rods are then co-planar, and the second runner can be adjusted for linearity. A datum plane is then available using the two runners and a straight edge, from which each support of the glass bottom can be adjusted to a definite position.

That the mechanics of construction can be made satisfactorily is shown by the fact that in one case of a bottom 3 ft 6 in by 2 ft (106·7 by 61 cm), the bottom was completely removed from the frame after six months, and replaced without a single support having to be altered in position.

There remains the actual numerical location in terms of coordinate position of the probes relative to the model. In spite of many mechanically simpler alternatives invented, scales and verniers along the runners offer the most satisfactory solution, giving readings to 0·1 mm. As is often the case, the electrical measurements are usually more sensitive than the mechanical ones.

Detailed results obtained from a tank of this type are to be found in ref [3]. A photograph of the large tank referred to above is shown in Fig 8.

Wedge Tanks

In the above discussion, structures of axial symmetry have been treated with half-models. These can, of course, be expensive to make, and an alternative which has often been used is the wedge tank. This is in effect to make the model a sector terminating in the axis and bounded by two insulating planes. If the sector is of small angle, the circular shapes can be replaced by plane elements. In the conventional tank one of the insulating planes is the free surfaces, the other an insulating sheet. Difficulties have always been experienced with this rather attractive idea. Meniscus troubles at the emerging insulator exist, and probe penetration has to be controlled very carefully. Attempts to use wedges of this type with the inverted tank have led to interesting results which shed light on the normal type as well.

First, the wedge in the inverted tank has to be of the form of Fig 9. This is necessary to maintain zero radial field at the apex. If one side is omitted, the small but finite gap leads to severe distortion. It was found on comparison with a half-model that the apparent field near the apex was very much lower in the wedge model than could be accounted for by dimensional tolerances. The explanation turned out to be that the probe perturbations near the apex are intensified by the image fields in the insulating boundaries. An alternative way of looking at this is to consider the local field perturbations, which extend to much greater distances than the distance between the sheets. The effect can be reduced by decreasing probe hole sizes. Since the perturbing effect of the 'hole' probes are about ten times less than any wire probe, measurements of fields in ordinary wedge tanks must be highly suspect.

Fields of Use of the Electrolytic Tank Analogue

The electrolytic tank basically solves Laplace's equation. Any section of engineering problem which can be reduced

to this equation can therefore be solved with its aid. The obvious analogue discussed above is that of the electrostatic field. Others are the flow of incompressible non-viscous fluids, heat flow, and the magnetic field in substances of constant permeability. Although practical problems are often only very approximately equivalent to these ideal cases, solutions are very valuable as stepping stones to more accurate solutions. Another exact application of some interest is in the sphere of electrical networks, in which impedance and transfer functions can be shown to have properties akin to electrostatic systems. Further information may be gained from refs [4, 5, 6 & 7].

More complicated problems not directly involving Laplace's equation can also be solved. A problem of interest is the electrostatic one involving materials of different dielectric constant.[4] In the analogue different dielectric constants can be represented by different conductivities, but these can only be achieved by varying the depth. In order to distribute the current uniformly over each region, the boundary line at the change of depth is marked by a row of vertical conducting pins designed ideally to present zero impedance to normal fields but the electrolyte impedance to transverse ones.

Problems with varying magnetic permeability may be similarly tackled, but it is evident that model-making becomes more tedious when such subterfuges have to be adopted.

Poisson's equation is also of considerable importance, and even more difficult to solve. An example of this equation is in the determination of space charge forces in electron beam devices. The actual distributed charge produces its own field. Simulation of this requires injection of current into the tank at points occupied by the charge. This can be done by means of an array of probes at points on a close mesh.[8] It is also possible to produce similar effects by modelling the tank bottom.[9] This process is essentially one of taking a three-dimensional problem with a plane of symmetry and interpreting the answer in a different way; *e.g.* in the plane of symmetry the equation will be

$$\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)V(x, y, o)=-\left.\frac{\partial^2 V}{\partial z^2}\right|_{z=o}$$

and the term on the right is interpreted as the space charge density in a two-dimensional problem.

More elaborate devices involving an electrolytic tank can be made. The tank at Cambridge has been built as part of an automatic electron trajectory tracer.[10] The tank provides the field at any point occupied by the electron, and this gives the acceleration on the electron. A small digital computer is then used to integrate the equations of motion and to move the probe in the path the electron would follow.

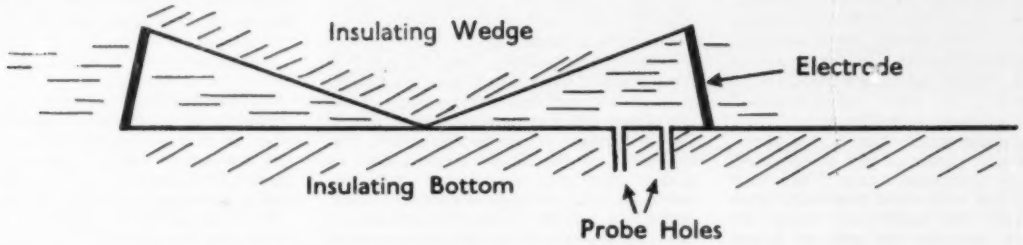


Fig 9. Form of the wedge used in the inverted tank as an alternative to a half-model

Conclusion

The electrolytic tank can be made into a versatile, accurate and reliable piece of equipment. It can be used easily to obtain solutions of Laplace's equation to a high degree of accuracy, and less easily to solve other problems. With these other problems, other analogues such as the resistance network[11] are also available, and the relative merits require careful consideration.

REFERENCES

1. Fortescue, L. L., and Farnsworth, C. W., *Trans. AIEE*, **32**, 1913, p 757.
2. Sander, K. F., and Yates, J. G., 'The accurate mapping of electric fields in an electrolytic tank', *Proc. IEE*, **100**, Pt II, No 74, April 1953, p 167.
3. Sander, K. F., and Yates, J. G., 'A new form of electrolytic tank'. *Proc. IEE*, **104**, Pt C, No 5, 1957, p 81.
4. McDonald, D., 'The electrolytic analogue in the design of high voltage transformers', *Proc. IEE*, **100**, Pt II, No 74, April 1953, p 145.
5. Diggle, H., and Hartill, E. R., 'Some applications of the electrolytic tank to engineering design problems', *Proc IEE*, **101**, Pt II, August 1954, p 349.
6. Hartill, E. R., McQueen, J. G., and Robson, P. N., 'A deep electrolytic tank for the solution of 2- and 3-dimensional field problems in engineering', *Proc. IEE*, **104**, Pt A, October 1947, p 401.
7. Boothroyd, A. P., Cherry, E. C., and Makar, R., 'An electrolytic tank for the measurement of steady state response, transient response and allied properties of networks', *Proc. IEE*, **96**, Pt I, 1949, p. 163.
8. Hollway, D. L., 'The determination of electron trajectories in the presence of space charge', *Aust. J. Physics*, **8**, 1955, p 74.
9. Goudet, G., and Musson-Genon, *J. Phys. et Radium*, **6**, 1945, p 185.
10. Pizer, H., Yates, J. G., and Sander, K. F., 'An automatic electron trajectory tracer', *J. Electronics*, **2**, July 1956.
11. Liebmann, G., 'Resistance Network Analogues', Proceedings of the *International Analogy Computation Meeting*, September 1955, p 346.

Notes

Short-circuit testing of air-blast circuit-breakers

The Association of Short-Circuit Testing Authorities (ASTA) has recently formulated rules to secure uniformity in the short-circuit testing of air-blast circuit-breakers for ac systems pending the publication of a British Standard. Until then, the Association will issue Certificates of Short-circuit Rating for circuit-breakers which successfully pass the prescribed tests.

The publication of these rules (ASTA No 17: 1957) fills a long-standing need for a uniform method of interpreting the results obtained and the assessment of the performance of the circuit-breaker. Problems other than those covered by this publication will undoubtedly occur from time to time, and as they occur ASTA will make decisions in each individual case which will be recorded for future inclusion in the Rules.

One very relevant problem is that of circuit severity, *i.e.* rate of rise of restriking voltage and amplitude factor. Until such time as values now under discussion have been agreed, this publication makes no attempt to pre-judge the issue of circuit severities. In Clause 21, however, the rules provide that the inherent test circuit severity for each of the test duties shall be not less than the appropriate rated circuit severity assigned to the air-blast circuit-breaker.

It is considered that this new publication will provide a useful guide to short-circuit testing stations and to all those interested or concerned in the testing of air-blast circuit-breakers.

It is obtainable (price 10s) from The Association of Short-Circuit Testing Authorities, 36 Kingsway, London, WC2.

'Dry' cooling towers

A development which may have far-reaching effects on the future siting of some power stations is announced by the *English Electric Co Ltd*. This is the 'dry' cooling tower system proposed by two Hungarian engineers, Prof L Heller of Budapest University and L Forgo, in a paper delivered at the last World Power Conference in Vienna, and now being developed by *English Electric*. It was recently stated by the Central Electricity Generating Board that negotiations are in hand for the design and construction of a commercial scale installation based on this system.

Hitherto, the only practicable method of condensing the steam in large plants involves the circulation of considerable volumes of cooling water through surface condensers—a requirement which usually restricts the siting of power stations to rivers, lakes, or coasts. An essential feature of the new system is the injection of pure water into the steam, and the cooling of the mixture of water and condensate by air in large heat-exchangers or coolers of special design installed round the face of the 'dry' cooling tower. The same water supply is used again and again, and only comparatively slight losses have to be made up. Moreover, since this is a completely closed system, the water in circulation will be of condensate purity and internal corrosion troubles in the plant should be materially reduced.

The air-flow through the cooler is produced by either natural draught or induced-draught fans, depending on such factors as fuel cost, ambient temperature, and size of unit.

Each projected installation requires an individual economic study, and therefore overall costs cannot be generalized. *English Electric* states, however, that studies indicate that, as soon as cooling water becomes a special problem for any reason, the new system will frequently be more economical overall than conventional systems, providing a technically sound and potentially economic solution to the problem of siting a power station at a distance from natural sources of cooling water.

Catching them young

Translated into modern terms, the desire of most boys to be engine drivers when they grow up was well exploited by many of the exhibits at this year's National Schoolboys' Own Exhibition in London last month. The attraction of the latest developments in science, electronics, space travel, and satellites drew boys and girls of all ages in their thousands, and the event presented admirable opportunities to fire the imagination of the youngsters with the exciting choice of jobs and careers to be found in the electrical industry. Accordingly, many firms and organizations made a prominent feature of their education and training schemes.

Thus the *Metropolitan-Vickers Electrical Co Ltd* had an attractive display of models and photographs showing the wide range of the company's products and achievements, including working models of electric and diesel-electric locomotives and the 138,000-kW hydro-electric generator for Canada, while demonstrations of many electrical and electronic devices were staged. Experts from the company's education department were continuously available on this stand to answer questions and discuss problems with parents.

Another BEAMA member—the *Morgan Crucible Company*—featured a closed-circuit television camera channel so that visitors could see themselves on television, the object being to emphasize the close connexion between the firm's products and the television industry. Here again there was a special staff to deal with any inquiries about the openings for careers available in this organization.

The theme of the British Electrical Development Association's exhibit was 'Get up to date—go electric', with 'Dabble or Quit'—a novel electricity quiz—as the bait to educate visitors to the advantages of using electricity. Punch-card 'fruit' type machines were used for recording on each competitor's card his or her answers to the ten questions given, and each question was answered by actual demonstrations, some of them carried out by the competitors themselves. Thus electronic counters showed that the answer to the question 'How long would it take to count a million' was 26 days; a battery of electric kettles proved that it takes about 90 sec to boil the water for the morning tea; if the answer was 'No' to the question 'Do you have electric cooking at home', competitors were invited to try their hands at it there and then.

Throughout the exhibition, emphasis was laid on boys being actively engaged on some electrical pursuit, and one of the most important quiz bays was that dealing with careers in the electrical industry. Visitors over 14 who expressed an interest in this question were given individual attention.

The GPO showed the many kinds of jobs available in the electrical divisions of the Post Office Engineering Departments; the British Transport Commission had a large-scale 'Just the Job' display of a transport system with trains, buses, docks, etc., to show the visitors what a transport career can offer. Apprentices from the British Railways' training schools gave demonstrations of their work.

An electronic computer with punched-card equipment was demonstrated and explained by a team of experts who were kept very busy working out problems for schoolboys.

'The Moriston Story' on film

The story of the Upper Moriston Scheme, from the preliminary surveys to its completion last year, is told in a new film made by the Mitchell Construction Co, who were the civil engineering contractors for the project.

The film is in black and white in either 35 or 16 mm, and runs for 35 minutes. Copies are available on loan from the Mitchell Engineering Ltd, 1 Bedford Square, London WC1.

The Moriston Scheme is a project by the North of Scotland Hydro-electric Board to harness the waters of the River Moriston and its tributary the River Loyne to produce 213 million units of electricity a year and to have a capacity of 65,000 kW.

There are two large dams, one at the outlet of Loch Loyne and one at the outlet of Loch Cluanie. A tunnel conveys the water from Loch Loyne to Loch Cluanie, and another tunnel conveys the waters of both lochs to a power station at Ceannacroc. There are also a further large power station, dam, and tunnel in lower Glen Moriston, and subsidiary power developments on the River Doe and at Livishie.

An important and original feature of the constructional work was the use for the first time in Great Britain of wet-ground blast furnace slag by the Trief process in substitution for a considerable proportion of cement in the concrete of the dam. The decision to adopt this process was made after a deputation had investigated its use in the construction of a large dam by the French Electricity Board at Bort-les-Orgues in Central France. As a result, some 20,000 tons of ordinary cement were saved and thereby freed for export and for other home uses.

Some notes on non-destructive testing

The December 1957 issue of the *SS Newsletter* (issued by Solus-Schall Ltd) contains as its principal feature the first of a series of articles on ultrasonic testing.

This article, which is by way of an introduction, covers in general terms the three methods of ultrasonic testing: the impulse

reflexion method (which is the most frequently used); the transmission method; and the resonance method, with their respective advantages and disadvantages. The three types of CRT screen display—A-scan, B-scan, and C-scan—are described, and the choice of suitable frequencies discussed.

Other features in this issue describe an X- and Gamma-ray detection doserate meter; X- and Gamma-ray detection in geological survey; and quality control by eddy current methods.

Unusual fluorescent lighting installation

The lighting installation recently supplied by *Crompton Parkinson Ltd* for the new maintenance depot and offices of Reed Transport Ltd is a notable example of the use of fluorescent lighting in large open working areas. Reed Transport Ltd is part of the large Reed Paper Group, and the new depot provides facilities for the regular servicing and overhaul of a fleet of 200 commercial vehicles and 80 trailers, 100 cars, and 50 items of specialized plant and equipment including cranes, dumpers, fire appliances, and ambulances. It is in action twenty-four hours a day, seven days a week, and the lighting scheme has been designed to meet all these specialized requirements.

The main garage floor area exceeds 14,000 ft² (1300 m²) and is provided with a general lighting level of 15 lumens/ft² (162 lm/m²) from a series of 80 W fluorescent fittings mounted 18 ft. (5·5 m) above floor level in shallow section lighting trunking fitted directly to the concrete roof beams.

The five-bay service dock, which is claimed to be the first one in Britain where fully loaded vehicles of up to 30 tons can drive on to all-steel tracks over the inspection pit, is equipped with special fluorescent fittings arranged along the sides of the bays and providing excellent under-chassis lighting. A Kelvin Norton system of low-voltage hand-lamps provides localized illumination to supplement the general lighting.

In the machine shop and other working areas, two-lamp fittings are used to provide lighting levels of 25 to 30 lumens/ft² (270 to 325 lm/m²) and in the two-story office block, lighting levels of 20 to 25 lumens/ft² (215 to 270 lm/m²) are obtained from Crompton diffusing panel fittings recessed in the false ceilings. Other electrical equipment supplied by Crompton Parkinson Ltd includes two 15-hp electric motors to drive the air compressors for the air-powered hand tools.

Lubricants for nuclear power stations

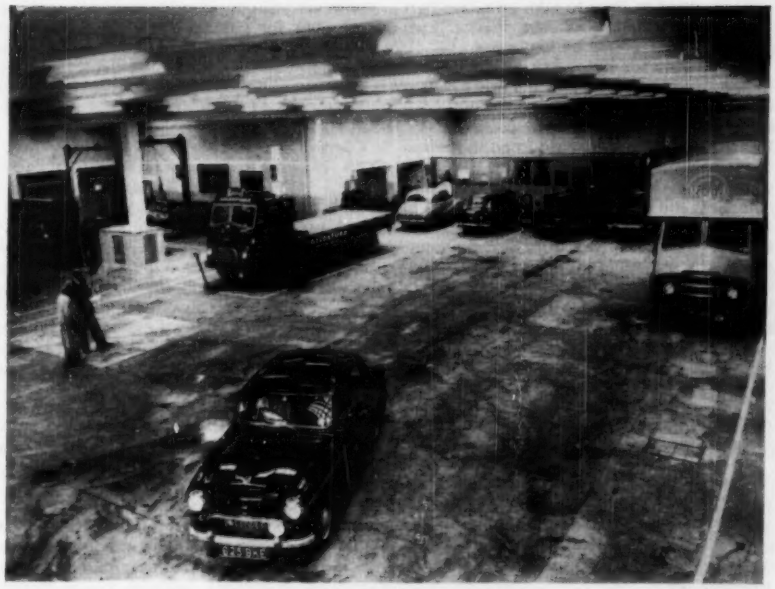
Lubrication problems in the 'inactive' portions of a nuclear power station are, generally speaking, basically similar to those encountered in conventional stations. Special problems arise, however, in the 'active' portions—within the pile itself and in its immediate vicinity, since lubricants subjected to nuclear radiation are liable to serious degradation.

The need for lubricants capable of giving satisfactory service under 'active' conditions has engaged the attention of the research laboratories of the *Wakefield Group* for some considerable time, and contracts have now been placed with *Wakefield-Dick Industrial Oils Ltd* by the Central Electricity Generating Board and the UK Atomic Energy Authority for lubrication at the new Berkeley and Chapelcross stations.

Of the four types of particle or radiation produced by the fission process—alpha, beta, gamma, and neutron—the first two are generally harmless to lubricants as they are absorbed by the shielding and structure of the pile. Gamma radiation and neutrons, however, can have the effect of thickening lubricating oils to a point where they become unserviceable, while greases can be similarly affected to produce hard solids.

The viscosity increase appears to occur in two stages. At first, oil may become only slightly thicker and grease may actually become softer, but in the second stage, the viscosity increase and the solidification proceed more rapidly until the lubricant becomes useless.

There is, reports the Wakefield Group, no certain way of forecasting from the behaviour of one material what is likely to happen to another when subjected to radiation, and research on lubricants for nuclear power stations involves the subjection of samples of many different products to actual radiation in an atomic pile or in the presence of another radiation source. Very useful information has been obtained in this way and certain types of petroleum-based lubricants have been shown to resist the thickening effect more strongly than others, while certain materials not of petroleum origin have shown considerable promise.



Fluorescent lighting by Crompton Parkinson Ltd in the new maintenance depot of Reed Transport Ltd. This shows the 60 ft (18 m) span marshalling area (see story in Col 1)

International study days on thermal and hydraulic power plants

Under the auspices of the 'Association des Ingénieurs Électriciens sortis de l'Institut Électrotechnique Montefiore' of Liège, a series of 'Study Days' on boilers, steam and hydraulic turbines and alternators will be held next May from the 27th to 31st inclusive. The meetings will take place in the Palais des Congrès at Liège, and a series of papers on the above subjects will be presented for discussion by specialists from Belgium and other countries. The Association states that the participation of many delegates from Britain, America, Belgium, France, Germany, and Switzerland is already assured.

The papers will be grouped in four sections: (1) Boilers; (2) Steam Turbines; (3) Hydraulic Turbines; (4) Alternators. Sections 1 and 3 will be held simultaneously on Wednesday 28 May, Section 2 on Thursday 29 May, and Section 4 on Friday 30 May. Technical visits are planned for Tuesday 27 May, and a visit to the Brussels International Exhibition will be organized for Saturday 31 May. A programme of tours and visits will be arranged during the Study Days for ladies accompanying the delegates.

The official languages will be English, French, and German, with instantaneous translation facilities available for members of the Study groups. The papers will be published and sent to all delegates in advance of the Study Days.

Registration fee, which includes the papers for any one section, is 600 frs (Belgian). Papers for the other three sections can be obtained at an additional fee of 150 frs (Belgian) for each section.

Further information from the Secretary, AIM, 1 rue de Spa, Liège, Belgium.

Death of Mr Ernest A Reid

We record with great regret the death of a personality well known to many BEAMA members—Mr Ernest A Reid, President of Ernest A Reid, SA, engineers and manufacturers' representatives, of Lima, Peru.

Mr Reid, who was 72, was born in Callao, and educated in Peru and in Great Britain, where, during his student days, he served as a student apprentice with Dick Kerr & Co Ltd (now the *English Electric Co Ltd*). He

ater returned to Peru to take an active part n the management of the Piedra Liza Foundry, then owned by his father.

He left Peru for Great Britain in 1920 and in the following year joined the Canadian & General Finance Co, Ltd, a subsidiary of the Brazilian Traction, Light & Power Co. For many years, until he returned to Peru in 1949, he was manager of the engineering, purchasing, and shipping department of that company, the name of which was changed in 1947 to the Canadian and Brazilian Services Ltd. During his absence from Peru he maintained close contacts with its national activities and in 1944 was awarded the Peruvian Order of the Sun for his services to Peru in Great Britain.

Mr Reid was a member of the Institute of Export, a Founder Member of the Institute of Fuel, and a Fellow of the Royal Society for the Encouragement of Arts, Manufactures and Commerce.

New standards for rubber-insulated cables

Important changes in British Standards for rubber-insulated cables which became effective on 1 January are detailed in the following publications:

- Amendment No 3 to BS 7 : 1953 for rubber-insulated cables and flexible cords for electric power and lighting.
- A new edition of BS 883 : 1958 for cables and flexible cords for electrical equipment of ships.
- A new Standard BS 2899 : 1958 for vulcanized rubber insulation and sheath (including polychloroprene) of electric cables.

The changes have a twofold purpose. The first is to embrace the recommendations of the 1953 and 1957 Commonwealth Standards Conference for a reduced rubber content for general-purpose insulation, and this is now specified in the new BS 2899, the amendment to BS 7 (and amendments to other Standards relating to rubber-insulated cables), and the revised BS 883. The second purpose is to take advantage of the more economical methods of construction made possible by modern manufacturing processes by the omission of tape from the common sizes of conduit wiring cables, and this is also covered in the amendment to BS 7.

Reduced rubber content

BS 2899 replaces the clauses in the existing Standards on the quality of rubber insulation and sheath. The principal change reduces the rubber content of general-purpose insulation from 45-50 per cent by weight (equivalent to 70-75 per cent by volume) to 50-60 per cent by volume, resulting in a compound similar to Type 2 specified in Defence Specification DEF 15 used by government departments. The Standard also gives requirements for fire-resisting and ozone-resisting insulation, and for four types of sheath. The specified rubber content of general-purpose sheath is somewhat less than is required by BS 7 : 1953. Methods of test, similar to those in BS 7, are prescribed for the various types of insulation and sheath.

One result of the reduced rubber content of general-purpose insulation (dealt with in the amendments to BS 7 and other specifications) is a reduction in the insulation resistance of finished cables. The new values are, however, still considerably greater than those accepted for corresponding PVC-insulated cables, and it is understood that the IEE has consequently not found it necessary to modify its Regulations for the Electrical Equipment of Buildings.

Changes in cables for use in ships

BS 883 : 1958 aligns the standard with BS 7 : 1953, BS 480 : 1954, and BS 608 : 1956 for rubber-insulated, paper-insulated, and varnished-cambric-insulated cables respectively, as far as the special conditions of shipboard use permit. One additional type of cable—polychloroprene-sheathed without braid—has been introduced, but tough, rubber-sheathed cables (apart from flexible cables and flexible cords) are no longer specified for use in ships; they have been superseded for this purpose by the more fire-resistant polychloroprene-sheathed cables.

The quality of rubber insulation, rubber-like fire-resisting insulation, rubber sheath and polychloroprene sheath is defined by reference to BS 2899. The requirements for paper insulation and varnish-cambric-insulation are similar to those of BS 480 and BS 608 respectively. The section on mineral-insulated cables has been omitted from this edition of BS 883, because a new British Standard for mineral-insulated cables, which will be equally applicable to cables for use on land and in ships, is expected to be published shortly.

Revision of BS 7

The two principal purposes of Amendment No 3 to BS 7 : 1953 are to substitute references to BS 2899 for the existing requirements for rubber insulation and sheath, and to provide for the manufacture of the smaller sizes of braided and compounded cables without a layer of proofed tape over the insulation.

The change in rubber content of general-purpose insulation introduced in BS 2899 has made it necessary to revise the values of minimum insulation resistance specified for cables made with this kind of insulation. The new values are generally about 25 per cent of those formerly required. Revised tables of dimensions are given for those types of cable affected by the omission of proofed tape from the smaller sizes, and the opportunity has been taken to specify some of these dimensions to a greater degree of accuracy than formerly in order to obviate difficulties in inspection.

The amendment makes a number of other changes which affect HSOS cables, tough, rubber-sheathed flexible cords and unkinkable flexible cords.

The following amendments, necessitated by the changes in BS 7, were also published on 1 January:

- Amendment No 1 to BS 708 : 1957 'Trailing cables for mining purposes' (PD 2936).
- Amendment No 2 to BS 1116 : 1956 'Flexible trailing cables for quarries and metalliferous mines' (PD 2937).
- Amendment No 3 to BS 1862 : 1952 'Cables for vehicles' (PD 2938).
- Amendment No 1 to BS 2008 : 1953 'Vulcanized rubber-insulated wire armoured cables for collieries' (PD 2939).

CMA comments

Reviewing these changes, the Cable Makers Association comments that the type of specification which lays down specified tests and minimum performance requirements allows manufacturers greater flexibility in the choice of materials, and this could be a most important consideration in obtaining a measure of price stabilization.

Rubber technology is approaching an exact science and many cable technologists believe that laboratory tests have reached a stage where it should be possible to dispense with specifications defining a particular type of compound by general composition clauses, and to rely instead on a type of specification consisting only of performance tests and requirements so framed that any 'rubber' insulation meeting the combination of requirements must necessarily be of satisfactory quality.

In view of the known intention to manufacture synthetic rubber in this country and the need to be increasingly competitive in world markets, the Association holds that it is most desirable that specifications should give manufacturers the greatest freedom in producing technically satisfactory cables. With this in view, the Cable Makers Association is conducting experimental work with the object of framing proposals for a British Standard based purely on tests and performance requirements which will ensure an entirely satisfactory product, while allowing manufacturers the economic choice of natural or synthetic materials.

Copies of the Standards mentioned can be obtained from the British Standards Institution (Sales Branch), 2 Park Street, London, W1. Prices: BS 2899, 5s; BS 883, 15s.

Computer works out new time-tables

The introduction of new forms of railway traction (see page 33) means that new train timings will have to be worked out, since the characteristics of the new diesel and electric locomotives are different from those of steam. The new timings are necessary to serve as a basis for new time-tables and to get the maximum advantage from the new services.

There are many ways in which these calculations could be made, but British Railways have taken advantage of the experience of the *English Electric Co Ltd*, who had already used their electronic computer 'Deuce' in their own development of traction units.

Accordingly, the firm has now done a series of such calculations for the BR London Midland Region. These covered the route from London to Derby, and dealt with diesel-electric locomotives of two different tractive characteristics, with two different weights of train for each, and in both directions. The calculations allowed for the variations of the tractive effort of the locomotives with speed, the frictional and other resistances to the train, the actual gradients of the track, speed restrictions, and stops at stations.

The results at each station and at each change of gradient were punched on cards, from which they were subsequently printed.

The time taken for each calculation was about five minutes, of which at least half was occupied in punching the cards, so the net calculation time taken by 'Deuce' was equivalent to a train speed of about 4000 mph (6437 kmph).

Industrial cooking equipment

ITS DESIGN, DEVELOPMENT, AND APPLICATION

*R I Tompsett**

Of fundamental importance in building and maintaining a high standard of food operations is the provision of a planned kitchen in which adequate attention has been paid to the composition and design of the cooking equipment. Ease of maintenance and of use are now considered of equal importance to the actual cooking efficiency of the industrial unit. Moreover, modern factories develop at such a pace that provision has to be made right at the start for the easy extension of catering facilities.

In the majority of industrial kitchens, large or small, the central cooking range is the most important item of equipment, and, for that reason, manufacturers have given it considerable attention. The result is that one of the major post-war developments in industrial cooking equipment has been the design of ranges that can be mounted side by side (Fig 1), or back to back in multiples to form double- or three-oven ranges, and built up to make multi-oven units to meet individual requirements. One or two units can be added as and when required, suitable joining strips being provided. This facility is a great asset to the architect or authority who wishes to allow for an unspecified expansion at some later date.

The hob height has been kept down to 34 in (86 cm)—the correct working height—by the omission of a grill, as experience has proved that grilling cannot be carried out conveniently when oven and hot-plates are being used. It is preferable to install a separate grill in another part of the kitchen.

The unit range also has many advantages from the manufacturer's viewpoint. Foremost of these is ease of stocking. No matter what the size of an order, all that is necessary on its receipt is to ship the requisite number of units together with joining strips for simple erection on site by the contractors carrying out the installation. Furthermore, the arrangement allows the manufacturer to undertake quantity production—an advantage to the consumer in lowering the capital cost.

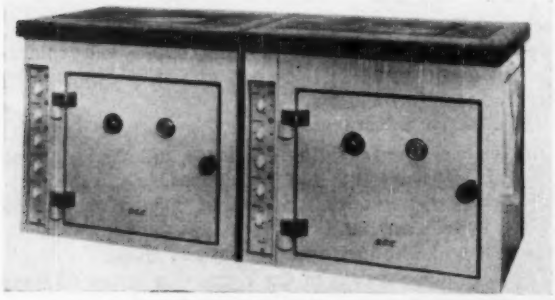


Fig 1. A typical arrangement of two ranges side by side

As the illustrations to this article show, manufacturers have paid considerable attention to the appearance of equipment. Apart from pleasing the eye, every attempt has been made to eliminate crevices and corners which would make cleaning difficult. All exterior surfaces are finished in easy-to-clean vitreous enamel, mottled grey in colour, with the exception of the hob, which is usually constructed from polished mild steel.

The maintenance engineer has not been overlooked by the designers of modern catering equipment, who have aimed at making it possible to carry out the majority of service operations from the front of the apparatus. For example, the range mentioned above is provided with a switchbox so constructed that when a retaining screw is released, the whole of the switch panel swings outward so that the fuses, pilot lights, and rotary switches are readily accessible for inspection and servicing (Fig 2). This arrangement is obviously necessary on unit type equipment, but it is also of great advantage if, when space is restricted, a range is fitted into an alcove or hard up against a wall, making access through the side impossible. Maintenance can thus be carried out quickly and with the absolute minimum of trouble to the catering staff. Because of this, most present-day equipment, including such items as boiling tables, roasting ovens, fish-fryers, and steaming ovens, is arranged in this way.

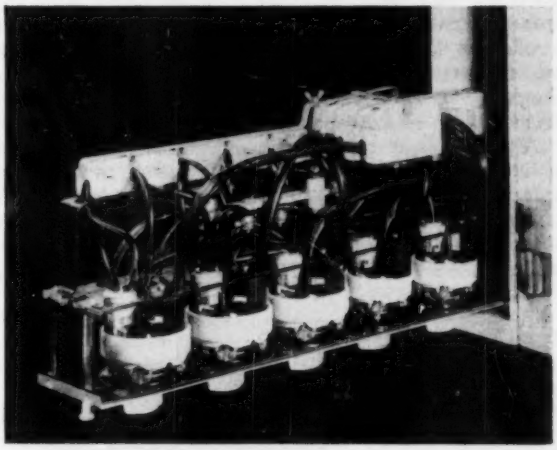


Fig 2. By releasing one screw, the whole of the switch panel is readily accessible

Fig 3 shows the switchbox of a 10 cu ft (0·28 m³) steaming oven, fitted with four 3 kW withdrawable type immersion heaters, controlled by two 3-heat rotary switches. Elements, pilot lights, and switches are readily replaced from the front of this equipment.

The use of stainless steel in the construction of catering equipment is becoming more popular. It has many advantages from the aspects of easy cleaning and durability,

* Industrial Heating Department, The General Electric Co Ltd.

but unfortunately remains expensive. Its use at the moment is restricted to hot cupboard tops and boiling-pan interiors. In the latter it stands up to the corrosive effect of some vegetable salts better than any other material.

Stainless steel has also been used to advantage in the construction of fish-fryers, especially those employing elements directly immersed in the frying oil. These have the heat right where it is wanted and recovery times are extremely fast—an important feature of fish-fryer design. The pan of the fryer illustrated in Fig 4 is constructed entirely from welded stainless steel and has a stainless steel heat exchanger and thermostat tubes. The base of the pan, below element level, is shaped down to a full bore draw-off tap used to drain the fat for cleaning purposes. Access to this tap is obtained in the void under the pan. A perforated stainless steel tray is provided over the element tubes to support the baskets. The removable front panel, held in position by knurled nuts, gives easy access to the withdrawable cartridge-type elements and thermostat. All fuses, the pilot light, and switch are accessible from the front. When frying is finished the frying-baskets can be hooked on the bar provided and surplus fat drained back into the pan. When not in use the cover folds down over the pan. This unit fryer can also be built into multiples to form double- or three-pan fryers as required.

Although most catering requirements are standard to a point, a manufacturer will sometimes be asked to design something to meet the individual requirements of a particular client. An example of this is the island range built to suit London County Council requirements and installed at the Westminster Technical College. This is one of two island ranges installed and is a combination of ovens, both manually and automatically controlled, interspersed with boiling tables and having a *bain-marie* hot cupboard at one end. These ranges are used for training students in the School of Cookery.

Fig 4 The fish-fryer described in the text

With the outstanding developments that have taken place since the war in sea and air travel, the catering equipment manufacturer has had to develop special apparatus to meet the requirements of low voltages, lightness of weight, and durability. Fig 5 is an example of a range designed to withstand the rigours of marine use. Complete with storm rail and fiddle bars, the total weight of the range is about 4 tons. It is constructed basically of cast iron and sheet steel. Fig 6, however, illustrates the other extreme: an aircraft oven which has a total weight of 88 lb (40 kg). Constructed of aluminium, with a stainless steel interior, the double compartment air circulation-oven

Fig 3. The front of a typical steaming oven with switchbox closed (above) *and open* (below) *for easy replacement of components*

is used for heating frozen-food meals on high-density seating aircraft. It can heat over 60 passenger meals.

Technical Developments in Cooking Equipment

One of the biggest post-war developments is the replacement of the old pattern open coil and strip elements by sheathed-wire elements.

A few of the advantages are:

(*a*) They ensure maximum efficiency and can be placed exactly where the heat is required.
(*b*) Their construction is such that they will withstand rough treatment.
(*c*) They can be bent into almost any shape.
(*d*) The metal sheath of the element is insulated from the live spiral and may be earthed so that there is no danger of shock through touching the sheath.

Sheathed-wire elements are constructed by placing a helical coil of high-grade nickel chromium resistance wire absolutely concentrically in a metal tube and then filling the tube with a special magnesium oxide powder. The tube is subsequently reduced in diameter so that the magnesium oxide is solidly packed and the coil retained in its central position with an even thickness of insulation separating it from the metal sheath along its entire length. The outer sheath of this type of element is manufactured from $\frac{3}{8}$ in (9·53 mm) diameter tube, and in any length up to 100 in (254 cm). The loading per inch (2·54 cm) run is

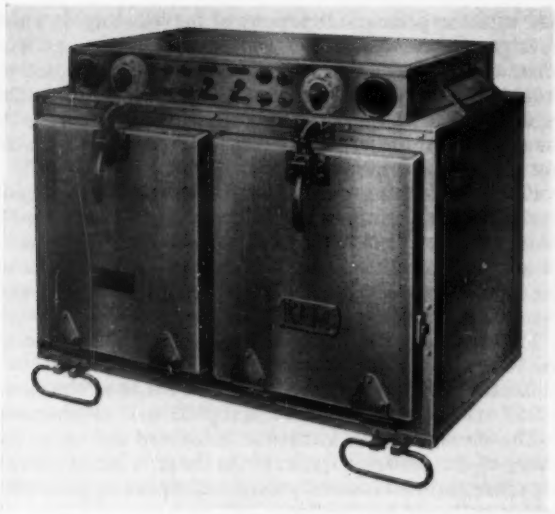


Fig 6. An oven specially designed for use in aircraft. Its total weight is only 88 lb (40 kg)

restricted by the maximum permissible sheath-surface temperature according to the material used.

Where thermostatic control is applied to equipment such as roasting ovens and hot cupboards, Alumbro sheathed elements can be fitted, but where control is by 3-heat switch, then Inconel sheathing should be used.

There are, of course, many terminal arrangements for this class of element. The most commonly used are: the flexible beaded tail; ferrules and locknuts; and the pillar terminal.

Termination with a flexible beaded tail is used when there is direct connexion to busbars and no mechanical connexion is required. Ferrules and locknuts are used for direct connexion to busbars when a mechanical joint is required into a busbar chamber. The pillar terminal is used mainly for immersion heaters, or when a suitable terminal has to be left to receive electrician's wiring.

In a typical arrangement for the design of a hot cupboard, the Alumbro sheathed-wire element can be positively earthed to the main frame of the equipment. In this case, as each loop is some 40 in (101·6 cm) long, it is supported by bridges at suitable intervals. This particular hot cupboard also has elements similarly arranged in the base for heating the cupboard sections. The element coil can be terminated at a suitable distance from the flexible beaded tail terminal, thus creating a 'cool length' when entering wiring chambers. The wiring chamber is insulated from the main heat-source by $\frac{1}{2}$ in (12·7 mm) asbestos board, thus restricting the wiring chamber temperature.

Another terminal arrangement is adopted in the case of oven elements. A 7 cu ft (0·2 m³) oven, for example, uses four 1·2 kW sheathed-wire elements constructed with Inconel sheaths. Two elements are positioned down either side of the oven and held in position by the frame. It provides an example of elements terminated with screwed ferrules and locknuts which pass through the insulated roof of the oven into a busbar chamber running across the top. The locknuts ensure a good mechanical joint.

An example of a pillar terminal arrangement is to be found in the steam generation tank fitted to a 6 cu ft (0·17 m³) steaming oven. The tank has a total loading of 9 kW, comprising three 3 kW sheathed-wire immersion heaters, each having protective automatic trips. These have thermal cut-outs to guard against the possibility of the water level falling should the water supply ever be interrupted. The trip may be reset simply by pressing the button situated in the head of the heater. These special immersers, unlike the standard type, are fitted from inside the vessel in which they are to operate, the securing nut being on the outside. The automatic trip is a protective device against boiling dry, and not a form of heat control.

The sheathed-wire element, bent to a different shape, is also fitted to bulk water boilers. Should the apparatus be allowed to boil dry and the cut-out operate, the plunger can be reset through the aperture provided. By removing a cover plate the element can be replaced, if necessary. The protective automatic trip is for use on alternating

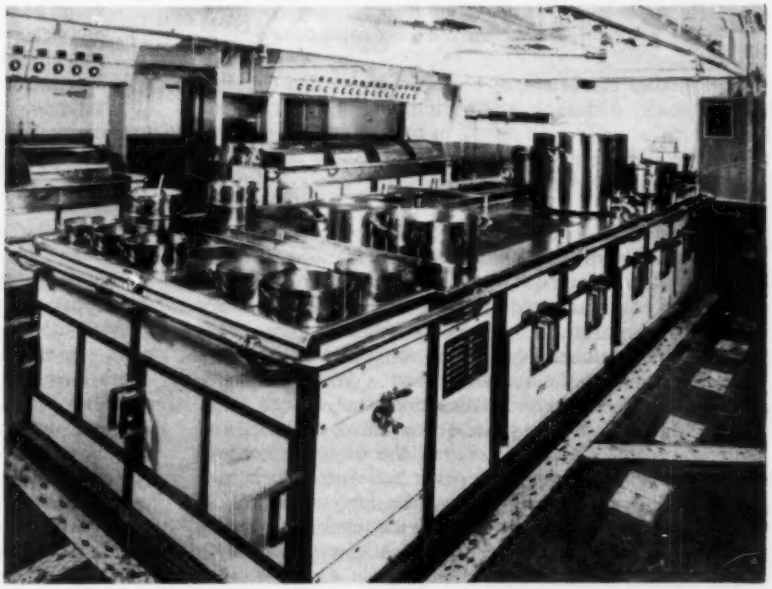


Fig 5. A range specially designed for marine use. Constructed basically of cast iron and sheet steel, its total weight is about 4 tons

current only. Brass pillar terminals finished in DNP are fitted.

Hot-plates

The 'solid hot-plate' retains its popularity with the catering trade. Manufactured of cast iron, they are of a suitable composition to withstand the temperatures attained in service and the very severe usage inseparable from industrial catering establishments. The heating element is embedded in refractory within the plate, arranged in two circuits for connexion to a 3-heat series-parallel switch. The average hot-plate is loaded to approximately 25 watts per sq in (6·45 cm^2).

Improvements have been made in the mounting arrangements to guard against spillage. Fig 7 shows the deep skirt on the plate which overlaps a smaller lip on the main hob casting. This feature prevents any spillage from the hot-plate coming into contact with the electrical connexions under the main hob. Adjustable screws are provided for both hot-plates and false hob, so that the whole top equipment can be correctly levelled.

Two standard sizes of hot-plate are now fitted to industrial cookers: 12 by 8 in (30·5 by 20·3 cm) loaded to 2·5 kW, and 8 by 6 in (20·3 by 15·2 cm) loaded to 1·2 kW.

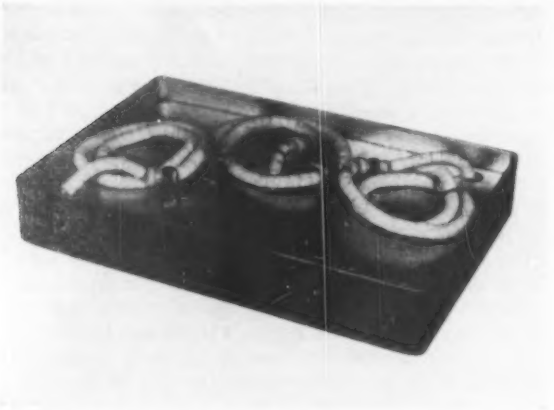


Fig 7. The deep skirt of this hot-plate prevents any spillage from reaching the electrical connexions

The smaller plates are, of course, mainly used for simmering work. Although it is quite common for a manufacturer to provide a 16 by 12 in (40·6 by 30·5 cm) hot-plate, this is made up of two standard 12 by 8 in (30·5 by 20·3 cm) plates wired to one switch.

Kitchen Planning

This is an era of specialization. The manufacturer of commercial catering equipment, apart from knowing the quantity of equipment required, its capabilities, and every aspect of its installation, must be a consultant to his client and advise on kitchen layout, planning, and design.

The location of the actual kitchen is very important, and in this respect there is little doubt that service direct to the dining-room is simpler to organize, quicker, and generally more efficient. However, the dining space will very often be used for many other activities which may strongly influence, if not govern, the final choice of its location. With careful planning, direct service can nearly always be arranged in a way that is satisfactory.

The kitchen should be placed so that it does not interfere with the principal functions of the building. It must have good light, ventilation, and drainage. Although it is often an advantage to place it close to the boiler house to reduce the cost of roads and mechanical services, it should be clear from dust and fumes. Care should, however, be taken to ensure that garbage bins and packing cases do not clutter the main approach to the building.

Kitchen planning consists basically of the intelligent application of certain prime principles. It is seldom possible to produce an ideal kitchen plan; inevitably it has to be a compromise between the ideal and the limitations of the site. The space allocated is frequently inadequate and the shape awkward.

Ideally the kitchen area required might correspond to the following general scale:

100 to 250 persons 4 to 5 sq ft (0·37/0·46 m^2)/person
250 to 1000 persons 3 to 4 sq ft (0·28/0·37 m^2)/person.

The actual size of a kitchen is influenced greatly by the shape of the available space. If the shape is inconvenient, the space required is usually increased. Speaking generally, a square-shaped kitchen lends itself to better planning. As a rule, the kitchen area is approximately a quarter of the space allocated for the dining-room.

The art of good planning is for the food to flow smoothly in one continuous process from the delivery of the raw material to its consumption. Planning, whatever the amount of space available, must allow for progression through certain stages. These are:

1. RECEPTION: Where all goods entering the kitchen are checked and weighed to permit accurate costing.
2. STORAGE: This should be divided into three definite sections: dry goods, cold store, and vegetable store.
3. PREPARATION: This should also be divided to provide one section for meat preparation, another for fish, and a third for vegetables. The large installation should also have a separate pastry-preparation bay.
4. COOKING: Division here is marked. There should be one section for dry equipment, such as roasting ovens and grills; one for fish-frying equipment; and another for wet equipment such as boiling pans and steam ovens.
5. ASSEMBLY: At this point all the sections should converge to produce the completed meal.
6. SERVICE: This is dependent upon the system employed, whether cafeteria or waitress.
7. WASH-UP: The final stage in the planning of any kitchen.

The actual choice of equipment is dependent on the class of establishment, whether hotel, restaurant, or factory canteen.

It has been a common fallacy to suppose that the more elaborate the menu, the more elaborate should be the equipment, but this is not so. In *à la carte* establishments the menu is very varied, and unless the numbers of people to be catered for are considerable, the size of each separate dish is insufficient to warrant individual equipment. In the majority of *à la carte* establishments, all operations are carried out on the central range. Where catering establishments operate a less varied menu, separate items of equipment are necessary to deal with the large quantity of steamed foods, fried foods, and boiled foods.

Each individual scheme must be treated on its merits according to the category under which it comes. The well-planned kitchen is the one where the various possible alternatives have been considered, and the most favour-

able selected. The kitchen planner must consider the kitchen as a whole working unit without giving undue emphasis to any one particular operation. It is not satisfactory to have cooking equipment installed capable of producing 500 lunches if the service facilities can only cope with 300 over the lunch period.

One of the most noticeable features of the modern post-war kitchen is its high degree of mechanization. Machines are available for potato peeling and chipping; for mixing, mincing, slicing, and dish-washing. Not only do these machines considerably reduce the labour required for preparation duties, but they add to the high standards of hygiene demanded in industrial kitchens to-day.

Cooking in the East

The rapid industrialization of many far-eastern countries has in many cases resulted in workers not being able to live near their place of employment and, as in the more industrialized West, canteen facilities have to be provided. When supplying equipment for such installations, the manufacturer should give careful consideration to the eating habits and style of cooking of the country concerned. For example, boiling tables are most widely used because in the majority of cases cooking is carried out on hot-plates and an oven is seldom used. It has also been found that deep-fat fryers are extensively required. Roasting ovens are usually required only for European style cooking.

Khima and tomatoes (minced meat curry) is a dish mainly cooked in large flat-bottomed pans on hot-plates. Fried dal (pulses fried with condiments) and Pulao (boiled rice lightly fried) are cooked in rice cookers and then lightly fried in flat-bottomed pans on hot-plates. An example of equipment specially designed for this type of cooking is the large-capacity rice cooker shown in Fig 8. It has a maximum capacity of 50 lb (23 kg) of dry rice, and takes approximately 90 minutes to cook a full charge. It employs steam for cooking the rice, as this method keeps the grains separate and avoids coagulation. Steam is generated in an electrically-heated boiler having a total loading of 9 kW, which operates at atmospheric pressure and maintains a constant cooking temperature. Operation is simple, and fully automatic protection devices are fitted. A separate wall-mounting control panel is supplied with the cooker.

The chapati (wheat dough) which can be cooked in various ways, mainly by light frying on a hot-plate or deep-fat frying, is a popular dish. Approximately 6 to 8 in diameter (15·2 to 20·3 cm), the chapati can be successfully cooked on a standard scone plate as used in this country.

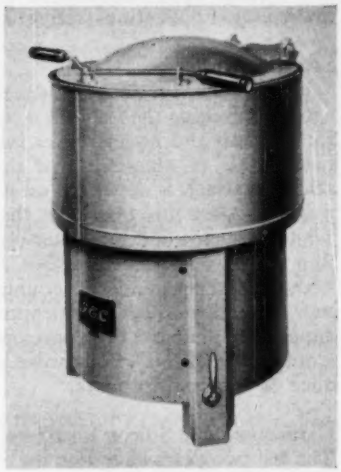


Fig 8. A large-capacity rice cooker designed for use in the East

Better results are obtained, however, by increasing the loading of the 3 by 2 ft (91 by 61 cm) table to 10 kW instead of its usual figure of 7·5 kW. In this way the chapati cooks in approximately 60 seconds.

It is, of course, difficult for the manufacturer to advise on suitable equipment when the type of food and method of cooking are strange to him. He should, therefore, obtain detailed information from his overseas customer if he wishes to ensure that the customer's requirements are met —a particularly important point if he wishes to obtain further business in the area.

Progress in semi-conductors and metal rectifiers

AT a private exhibition of semi-conductors and metal rectifiers at their works at Chippenham, Wilts., the Westinghouse Brake and Signal Co, Ltd, showed some of their latest developments in copper oxide, selenium, germanium, and silicon rectifiers. The description 'metal (or metallic) rectifiers' is the accepted term covering dry-contact rectifiers where rectification takes place between the junction of two dissimilar metals, which can be either a conductor and a semi-conductor, or two different semi-conductors. There are two important requirements which all types of metal rectifiers must fulfil: (*a*) low resistance to current flow in a forward direction, to give low power loss and to reduce heating; (*b*) high resistance to reverse current flow. While there is no limit to the magnitude of forward current, a limit is, however, set by the heating effect of the current and also by the safe reverse voltage which, if exceeded, might break down the barrier layer.

Copper-oxide Rectifiers

Copper-oxide rectifiers were first introduced some thirty years ago and had wide applications in electroplating, battery charging, X-rays, instrumentation, and so on. Other types have since been developed for heavy power requirements, but the copper-oxide rectifier is still preferred for certain duties in the field of electronics, telecommunication, and instrumentation where a stable source of low dc power is needed.

The rectifier element is a pure copper disc on which a layer of cuprous oxide has been formed by oxidation at high temperature. After the removal of an unwanted

surface layer of cupric oxide which unavoidably forms at the same time, a gold film is volatilized on to the cuprous-oxide surface to form a base for the contact. The barrier layer is formed between the junction of the base copper and the cuprous oxide. The elements can be assembled into any number of standard packs and these can be used in either single- or three-phase bridge connexions. Westinghouse have recently made improvements in these rectifiers, and they can now have a higher reverse operation voltage which reduces reverse leakage current for low-voltage applications; weight and size are also reduced.

Selenium Rectifiers

Selenium rectifiers were first developed over twenty years ago to overcome the limitations of the copper-oxide type for medium and heavy power loads. The elements are a metal plate of aluminium or iron and a thin layer of selenium which is deposited on it by a heat and pressure process. After this treatment the selenium is a vitreous semi-conductor and a counter-electrode of metallic alloy film is sprayed on to its surface. Rectification takes place between the selenium and counter-electrode junction. A new method in which the selenium is volatilized on to the supporting plate has been developed by the Westinghouse Company, and this will improve still further the performance of selenium rectifiers.

Germanium and Silicon Rectifiers

The last two years have seen the evolution of entirely new types of rectifiers which have resulted from a considerable amount of research into the electrical properties of the semi-conducting materials germanium and silicon. Many new techniques and processes of manufacture had also to be investigated, tested, and proven before production could be started. These problems have now been overcome and germanium and silicon rectifiers are available which are suitable for many conversion applications.

The process involves the growing or 'pulling' of crystals of germanium or silicon, and as this is similar for both crystals, a brief explanation is given of the manufacture of a germanium power diode. In the new Germanium and Silicon Building which has been opened at the Westinghouse works, germanium and silicon rectifiers are manufactured by a series of highly specialized processes in an air-conditioned work area which is maintained at a slight pressure so as to prevent the influx of unwanted impurities and which the operatives enter through an air lock where they change their shoes.

The germanium dioxide is first reduced to a metal and then refined to a very high degree. A measured percentage of selected impurities is now introduced to give the final crystal the right resistivity and conductance for efficient rectification.

The next stage is the growing of a single crystal which is carried out in a specially designed furnace with heavy thermal insulation, and the walls of the furnace are maintained at a constant temperature so as to keep the radiation from the growing crystal as low as possible in order to prevent stresses and other dislocations. Since stable orientation of growth is necessary to reduce lineage twinning and polycrystallinity the planes generally used are (100) and (111), the choice being determined by the degree of perfection required. The previously prepared metal is placed in a silica crucible and reduced to a molten state. A germanium seed crystal is then inserted in the charge and slowly withdrawn. The rate of withdrawal and the temperature of the molten mass govern the size and structure of the complete monocrystalline ingot. Both high-frequency and resistance furnaces are used, the eddy currents and convection currents respectively providing a stirring action so as to distribute the impurities evenly. The finished crystal is now cut into thin wafers by a diamond saw and the wafers are 'diced' into pellets. Pure indium (aluminium in the case of silicon rectifiers) is fused to one surface of the germanium pellet and rectification occurs at the junction of these two surfaces. The pellet is then soldered on to a steel base. Flexible connexions are made to the indium (or aluminium) and the assembly is enclosed in a hermetically sealed housing. This complete unit is known as a power diode.

Comparisons and Applications

Copper-oxide and germanium rectifiers have a lower voltage-drop when used at normal current densities than silicon and selenium. Copper-oxide and selenium rectifiers will withstand overloads of short duration, but germanium and silicon rectifiers, because of their low chemical mass and the high current densities at which they operate, will overheat very quickly. Precautions to prevent overloads damaging the unit must therefore be taken by using protection devices and by derating the rectifier when used under conditions where overloads may prevail. Natural air or forced air cooling is available on all types, and water cooling can be used on specially designed selenium and silicon rectifiers. The rectifier elements can be assembled in a number of ways and there are several methods of connexion to give half-wave and full-wave rectification of single- or multi-phase ac.

Metal rectifiers will cover all the application of ac to dc power conversion, and are economic and efficient in use. A few of the many uses of these rectifiers are for battery-charging, cathode projection, arc projection, electrolytic processes, electroplating, and traction. The engineer is now provided with a selection and range of metal rectifiers which will meet all his requirements in the field of instrumentation, electronics, or power application.

Characteristics of types of rectifiers

Rectifier	Voltage	Ambient temperature, deg C	Efficiency	Applications
Copper oxide	16	65	—	Instrumentation; electronics
Selenium	32	70	85-92	Electronics; power to 200 kW
Germanium	70-90	70	91-98	Electronics; high power at medium voltage
Silicon	100-300	160	83-98	Electronics; power up to 100 MW

Railway electrification forges ahead

NEW DIESEL-ELECTRIC LOCOMOTIVES HANDED OVER

'THE place on which we are standing is historic ground, for this platform is part of the original Euston Station, designed by Robert Stephenson and built in 1837, when trains were hauled out of the station by endless cables operated by stationary winding engines at Camden.

'Within a few years the wheel of history will have turned a full circle and cables will again be installed at Euston, but they will be cables of a very different order, conducting high voltage ac from the national grid for electrification of the train line from here to the North.'

This is part of the speech made by Lord Rusholme, a member of the British Transport Commission and Chairman of the London Midland Area Board, when he received from Lord Chandos, Chairman of the British Thomson-Houston Co Ltd, the first of the BTH series of main line diesel-electric locomotives now being built for the British Railways' Modernization Plan.

In formally handing over the new locomotive, Lord Chandos said: 'We in BTH like to look back more than 50 years when we supplied the equipment for more than 20 tramway electrification schemes. We remember particularly that in 1898 we received the contract for the power station, substations and locomotives for the Central London Railway. . . . To-day we have in hand for British Railways 30 power equipments for 1160-hp locomotives and 40 sets of traction equipment for 3300-hp locomotives which will be built in British Railways' Workshops. . . . In addition to the ten 800-hp diesel-electric locomotives, we are also supplying 25 complete locomotives of 3300 hp to use current fed from the grid.

'We have pioneered the use of germanium powered rectifiers, and we are supplying 35 ac multiple unit motor coaches. This is the first bulk order placed by any railway for germanium rectifiers for traction.'

The new BTH (British Railways' Type 1) locomotive is rated at 800 hp and is to be used primarily for main line freight duty. It has a maximum designed speed of 60 mph (97 kmph) and a maximum tractive effort of 37,500 lb (17,000 kg) at starting and is capable of exerting a continuous tractive effort of 20,000 lb (9100 kg) at 10·5 mph (17 kmph).

The locomotive has been designed to the general requirements of the British Transport Commission. The British Thomson-Houston Co Ltd, in addition to acting as main contractor for the whole locomotive, provided all the electrical equipment and carried out the erection and wiring of the equipment in the locomotive, and subsequent testing.

The mechanical structure was designed by the Clayton Equipment Co Ltd, Tutbury, in close collaboration with the British Thomson-Houston Co Ltd; this firm also built the bogies and the superstructure of the locomotive.

The underframe was built by the Yorkshire Engine Co Ltd, Sheffield, and the final assembly and painting of the complete locomotive were carried out by the same company.

The diesel engine was provided by Davey Paxman Ltd, Colchester, who also undertook the coupling up of the generator unit.

The locomotive is of generally conventional design, two 4-wheeled swing bolster bogies being used, fitted with SKF roller-bearing axle-boxes. The bogies are fitted with spherical centre pivots which support the body weight and transmit tractive force; side bearers to limit rolling are provided. There is a nose-suspended traction motor mounted on each axle, driving through single reduction gearing with a resilient gear-wheel.

The body comprises a power unit and radiator compartment, a driver's cab, and a short rear compartment housing the control equipment and certain auxiliaries.

The power equipment consists of a Paxman 16-cylinder Vee type diesel engine rated 800 bhp at 1250 rpm, coupled to a BTH 6-pole, 500-kW generator rated 690/337 V, 720/1320 amperes. The engine-generator set is resiliently mounted at four points on the two I-girder longitudinals which form the principal members of the underframe. The auxiliary generator is an 8-pole machine rated 40 kW, 110 V, 625/1250 rpm, the armature being carried on an extension of the main generator shaft. The exciter is mounted on an adjustable platform on top of the auxiliary generator frame, and is belt-driven from the main generator shaft.

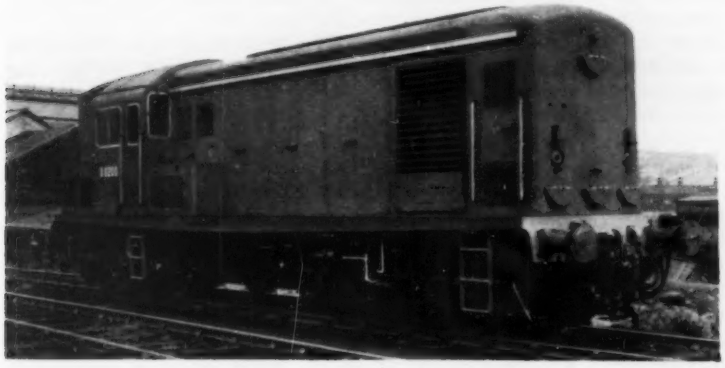


Fig 1. The new BTH 800-hp diesel-electric main line freight locomotive

The main control gear is located in the short compartment behind the driver's cab, which is remote from engine fumes and heat, where it is free from contamination by oil, water, etc., and is easy and convenient of access.

The driver's cab has two driving positions, diagonally situated, at each of which a comfortable swivelling seat is provided; to the right of each position is located a free-standing master controller, incorporating essential indicators, and to the left are the air and vacuum brake controls. The

less important instruments and alarms are mounted on the cab bulkheads.

The locomotive is fitted with compressed-air brakes, and with vacuum exhausters and control equipment for application of vacuum train brakes; it is arranged for operation in multiple with certain locomotives of similar or of greater rating in groups of up to three locomotives.

The first main line diesel-electric locomotive for the Eastern Region has also been delivered five weeks ahead of schedule. This locomotive—No D5500—is one of 20 Type 2 1250-hp diesel-electric locomotives which are being built by Brush Traction Ltd of Loughborough, with all the electrical equipment, including generators, traction motors, and control gear made by Brush Electrical Engineering Co, Ltd, and the diesel engines supplied by Mirrlees, Bickerton, and Day Ltd of Stockport—another company of the Brush Group.

D5500 is a mixed traffic locomotive of A1A-A1A wheel arrangement, weighing 104 tons in working order. The Mirrlees 12-cylinder Vee-form diesel engine develops 1250 hp and is coupled directly to a Brush electric generator which drives four traction motors located in the bogies. Maximum speed is 75 mph (121 kmph), and the locomotive can be used on passenger service, as it is equipped with an oil-fired steam boiler for train heating. It has a driving-cab at each end and can be operated singly or in multiple unit with two or three locomotives controlled from one cab.

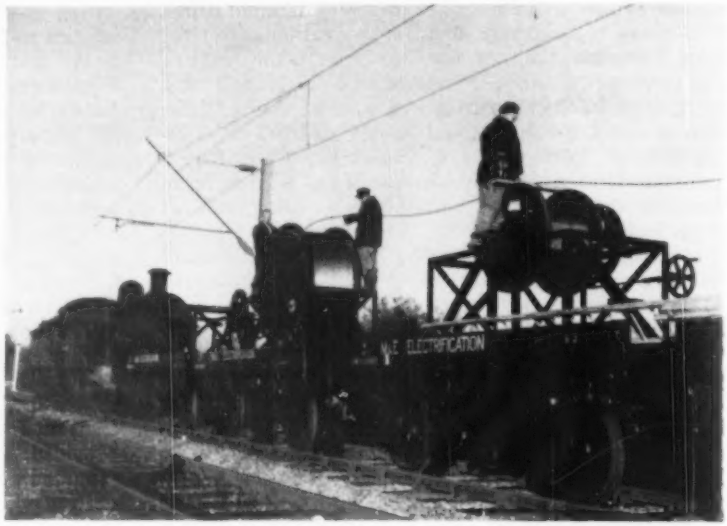


Fig 2. The special wiring train in action on the first section of the London Midland Region main line

Succeeding locomotives in this series are also well advanced, and a production rate of one every three weeks is being achieved.

Following Sir Brian Robertson's annual review of the British Railways' £1200 m modernization plan (THE BEAMA JOURNAL, May 1957, p 86), latest news shows that good progress is being made with many other schemes which form part of the plan.

Civil and electrical engineering work in preparation for the electrification of the Colchester–Clacton–Walton lines is being rapidly pushed ahead. It will be recalled that this project, which is due for completion this year, is being carried out on the new 25 kV ac system for the immediate purpose of testing the new equipment and multiple unit electric trains in the local services. Later, there will be a link-up with the extension of the electrification from Chelmsford to Ipswich.

Electrical Engineering Progress

OVERHEAD LINE EQUIPMENT

Installation work on this scheme was commenced last March. By the end of October, only a few foundations were outstanding and some 40 per cent of the supporting structures had been installed. The erection of the overhead line equipment was begun during October in the section between Wivenhoe and Alresford and was preceded by the fitting to the masts of the cantilever assemblies which support the conductors.

The new overhead equipment is designed for 25 kV. Simple catenary construction is employed using a 19/0·083 in (2·1 mm) stranded cadmium copper catenary, and a 0·166 in (4·2 mm) single cadmium copper contact wire attached to the catenary by droppers. The major portion of the overhead system will be of the automatic tension type, tensioning being applied by balance weights. At all terminal stations where running speeds are low, fixed tension simple catenary equipment will be installed.

The structures supporting the overhead line equipment are mainly of three types: BFB (broad flange beam) section, fabricated lattice, and fabricated welded rod. On open-route sections of the double-line track the great majority of structures consist of separate BFB masts acting as single-track cantilevers for each track.

With automatic tensioned equipment, the structure spacing is up to a maximum of 240 ft (73 m), this spacing being reduced to a maximum of 210 ft (64 m) where fixed tensioned equipment is used. All overhead line equipment structures are galvanized.

Overlap spans and neutral sections are being provided at convenient points along the line, which is thus sectioned electrically, not only at the feeder station and track-sectioning cabins, but also by switches at certain strategically placed overlap spans. The ac feeder cables from the feeder station will be laid in concrete troughing at surface level to their respective switches mounted on the neutral section structures.

Foundation work and erection of the supporting structures in open-country sections of the line is being carried out with the aid of the earth boring, steel erection, and concrete mixing units. At locations where steel was available at the time when foundation work was carried out, the method of construction evolved on the Eastern Region electrification of the Shenfield–Chelmsford and Southend lines was employed. This enabled the entire process of excavation, mast erection, and concreting to be performed in sequence during one operation.

Power Supply

SOURCE OF SUPPLY

Electrical energy at 25 kV, single phase, 50 c/s, will be supplied direct by the Central Electricity Generating

Board, Eastern Division, to Colchester feeder station, situated approximately ¼ mile (400 m) from Colchester passenger station. This supply will be transmitted to the feeder station by two 400 A, 10 MVA concentric type, 25 kV single-phase cables which will be connected to two 7½ MVA 132/25 kV single-phase transformers at the Colchester CEGB, Eastern Division, substation.

FEEDER STATION AND TRACK SECTIONING CABINS

At Colchester feeder station the two CEGB 25 kV single-phase cables will be connected to a three-section 15-panel switchboard. This switchboard incorporates two 300 MVA incoming supply single-phase oil circuit-breakers from which the single busbar will be fed. Two bus section switches will be connected on the busbar, making the three-section busbar switchboard. Also on this switchboard will be the 150 MVA 25 kV single-phase track-feeder oil circuit-breakers for supply to the Colchester–Clacton line and eventually to the main Colchester–Ipswich lines.

Alresford, Thorpe-le-Soken, and Clacton track sectioning cabins will parallel all sections of the overhead line conductors by means of 150 MVA single-phase oil circuit-breakers similar to those installed at Colchester feeder station.

SUPERVISORY CONTROL

As this is a pilot electrification project, a temporary supervisory control station will be provided adjacent to Colchester feeder station. From this control station, the circuit-breakers in the feeder station and track sectioning cabins will be remotely controlled together with eight power-operated switches which are to be erected at various locations along the line on the overhead equipment structures. Specially screened star quad-type pilot cables for the remote control of track switches and the oil circuit-breakers at Alresford, Thorpe-le-Soken, and Clacton will be laid in concrete troughing alongside the line in conjunction with the signal and telecommunication cables.

When the main line to Ipswich is electrified it is intended to dispense with the temporary control station at Colchester and to control power distribution from a main control room established elsewhere for dealing with the area as a whole.

SIGNALLING POWER SUPPLY

The supply for signalling will be provided for the Signal Engineer at Colchester feeder station and Thorpe-le-Soken track sectioning cabin. These supplies will be derived from two sources: the local supply network, and by transformation from the 25 kV single-phase traction supply. The latter supply will be regulated to cater for variations in the traction supply voltage.

On the Manchester–Crewe line, electrification is also well under way. A new power-operated signal box of the most modern design is to be built at Sandbach, using factory prefabrication to speed up construction on site. This will be followed by another box of similar design at Wilmslow.

The Sandbach box will come into operation in the middle of next year with a new multi-aspect colour light-signalling installation, and there will be electro-pneumatically operated points and continuous track circuiting.

For the new signalling installation Crompton Parkinson Ltd have supplied R/N/N type multi-core signalling cable to a new British Transport Commission specification.

The BTC has satisfactorily conducted a number of trial installations with this type of cable, and this latest installation on the 9 mile (14·4 km) stretch of line between Wilmslow and Slade Lane Junction in Cheshire is the first time this cable has been used in association with the 25 kV overhead electrification programme.

Each core consists of a 1/0·036 in (0·91 mm) copper conductor, vulcanized-rubber insulation (660 V grade) polychloroprene-sheathed and numbered taped. The appropriate number of cores, varying in this installation from 4 to 37 cores, are laid up with rubber fillings in the inner interstices, and a polychloroprene-sheath is provided overall. Compared with the cable customarily used for railway signalling work—multi-core, paper-insulated, and lead alloy sheathed type—the new R/N/N cable has the welcome advantages of considerably minimizing the task and the expense of jointing. The 660 V grade insulation is required for protection against the possibility of induced voltages under fault conditions in the traction circuit.

The installation of the signalling cables and their associated power cables (also Crompton) between Wilmslow and Slade Lane Junction was completed last November, the cables being run off from drums on a train of bolster waggons and laid direct in concrete ducts positioned in the 'cess'.

Under normal conditions, the signals will be operated automatically, with the entry and exit of the section controlled from boxes at Wilmslow and Slade Lane Junction. Other existing manned boxes at Styal, East Didsbury, Mauldeth Road, and Heald Green are to be replaced by ground frames which will enable shunting, etc., to be carried out at these points when required, with overall control from the box at the appropriate end of the section.

Meanwhile, British Insulated Callender's Construction Co, Ltd, are carrying out the erection of the overhead wiring on the Wilmslow–Mauldeth Road section of the main line between London and the North. The work is carried out from a special wiring train which works in two sections. The first section fits the insulators, cantilever arms, and tie rods to the steel masts; and the second attaches the overhead conductor wires to the cantilever arms.

The experience gained on this job will assist in planning the future employment of the train. Already two developments to speed up wiring work are planned and will be incorporated in the wiring train after testing. They are a special wire-tensioning vehicle and a wire-placing unit. The wire tensioner will deliver the wire to the workmen with just the correct amount of 'pull' on it instead of at a nominal pull direct from the drum. The wire-placing unit will allow easy control of the side-to-side 'stagger' imparted to the wire as it is erected. If the overhead wire were erected above the track in a straight line instead of a modified zigzag it would quickly wear a trough at one point in the carbon face of the pantograph.

This section of main line between Wilmslow and Mauldeth Road will be used as a proving ground for the new system while the rest of the work is proceeding. The overhead wires will be energized for experimental purposes by next May.

Work has also been started on stage 1 of the high-voltage ac scheme for the Glasgow suburban system. Pirelli-General Cable Works Ltd are undertaking the provision of foundations, the supply and erection of all structures, and the complete installation of overhead catenaries and contact wires on about 200 single-track miles (322 km).

The nuclear propulsion of ships

A REVIEW OF THE PRESENT POSITION

In view of the development which is taking place in the employment of nuclear power for the generation of electricity on land and the success which has attended these efforts, it is not surprising that attention is being turned to other possible applications, and in particular to the possibility of using this form of energy for ship propulsion. In dealing with this problem certain conditions have to be met which are not encountered with stationary plant. In particular, the ship must be able to manœuvre rapidly, thus necessitating sudden changes in the demand for steam, and the plant itself must continue to function however violent the motion of the vessel.

More fundamental is the choice of reactor which should be used, and this important subject was discussed in detail by Dr T W F Brown of Pametrada in a lecture recently delivered in Sweden to commemorate the 75th anniversary of Gustav de Laval's application for his first turbine patent.

Comparing the reactor variants which were possible, Dr Brown said that the choice was bewildering. For marine plants, however, the use of low enrichment fuels was of great importance and the types of reactors which could be used on merchant ships were relatively few. Of these, the beryllium-moderated gas-cooled reactor showed great promise but required considerable development. There were also the graphite-moderated gas-cooled reactor with natural uranium or low enrichment; the heavy water-moderated gas-cooled reactor with natural uranium; the pressurized water-moderated and cooled reactor; the boiling water-moderated and cooled reactor; the organic liquid-moderated and cooled reactor—all the last three employing enriched fuel only.

Alternatives Examined

Examining these alternatives in a paper read in November before the Joint Nuclear Marine Propulsion Panel, Sir Christopher Hinton and Mr R V Moore said that, although the pressurized water-moderated reactor was potentially of interest for marine propulsion because of its compact core, there was little possibility, with enriched uranium produced at a cost practicable in Great Britain, that it could show a profit. Under British conditions the most economical reactor was one of the graphite-moderated gas-cooled type, such as those installed at Calder Hall. These reactors were, however, of low rating and therefore unsuitable for use in ships. Nevertheless, if fuel elements of uranium oxide clad in beryllium were developed, the rating of the reactor could be raised and the size of the heat exchangers and the turbine equipment could be reduced. Higher steam pressures and temperatures would also be possible, thus raising the overall efficiency of the plant.

A Useful Investigation

In fact, by using fuel elements of this sort it should be possible to achieve ratings which would enable reactors of the graphite-moderated gas-cooled type to be installed on board ship; and with this end in view an investigation had been undertaken into the design of a 50,000-shaft hp reactor unit for driving a twin screw 100,000-ton dead weight ship.

In this design the reactor unit took the place of the boiler in a conventional power plant, with the other machinery remaining more or less unchanged. The diameter of the vertical pressure vessel was 18 ft (548 cm) and its heat output 180 MW. The carbon dioxide, the pressure of which was 315 lb/in² (21 kg/cm²) absolute, flowed downward through this vessel, which was supported directly from the tank bottom of the ship and was enclosed in a biological shield. This shield was lined internally with a thick mild steel plate in which 80 or 90 per cent of the radiation from the reactor was attenuated. The centre of mass of the graphite moderator was situated some 8 ft (244 cm) below the centre of roll of the ship. Two parallel cooling circuits were provided, each of which had its own heat exchanger and gas circulator.

Heat Exchanger Arrangements

The heat exchangers were supported with their axes horizontal to the side and forward of the reactor at tank top level. The two turbine-driven circulators lay between the inner longitudinal bulkheads in a separate flat some 15 ft (457 cm) above tank top level. The reactor was loaded and unloaded with uranium from the top, the deck for this operation being 20 ft (610 cm) below upper deck level, the intervening space housing the necessary machinery. The control room was positioned immediately aft of the reactor above the engine room in close proximity to the control equipment. The control rods were mounted in either side of the reactor vessel in compartments shielded from the gas ducts. The gas activity levels in the circulators and heat exchangers necessitated their being installed in lightly shielded compartments. The turbo-circulators and their condensers, the steam drums of the heat exchangers and their associated control equipment, which required maintenance, were situated outside this shielded area.

The weight per shaft hp for the reactor unit and all the machinery was about 500 lb (227 kg) of which nearly half was due to the radiation shielding and was much less than that of the Calder Hall plant. If a figure of 180 lb (82 kg) were assumed for the boiler and propulsion machinery for an equivalent conventional plant with turbo-electric drive, the nuclear plant was three times as heavy. Conventional plant, however, required 5000 or 6000 tons of bunker fuel at the outset of the voyage, while the nuclear plant needed only 15 tons of uranium, which was sufficient to fuel the ship for about a year. If the weight of bunker fuel was added to the weight of the conventional plant, then the weight per shaft hp rose from 180 lb to 425 lb (82 to 193 kg), which was roughly equivalent to the alternative nuclear plant. The space to accommodate the reactor unit and main machinery was

about 24 per cent of the length of the ship, compared with 17 to 18 per cent for a conventional tanker.

The weight per shaft hp of a gas-cooled graphite-moderated reactor could therefore be reduced to values acceptable for marine propulsion. As the rating increased, however, the core size for a given power output diminished and neutron leakage became prominent. To achieve high rating the surface to volume ratio of the fuel had to be increased, tending still further to spoil the neutron economy. This adverse effect required the use of slightly enriched fuel.

Economic Considerations

It was questionable whether there was any economic advantage in employing a highly rated graphite-moderated gas-cooled reactor to drive ships of the super-tanker class. At the present time the capital cost of nuclear power plant tended to be high and its fuel costs low in relation to conventional plants. The capital cost estimate for a 50,000-shaft hp plant indicated that it was about 50 per cent more than a conventional plant of similar output. The operating costs fell more steeply with increasing dead weight for the nuclear than for the conventional ship, and the same was true when the service speed was increased.

Manœuvrability Problem

Dealing with some of the important practical problems that occurred with the marine application of nuclear power, the authors said that in order to maintain the chain reaction when the reactor was operating at full power, sufficient enrichment must be included in the fuel to compensate for the neutron loss by xenon absorption. In addition, if the reactor were shut down or its output reduced, the neutron flux collapsed and the build-up of the xenon 'poison' was accentuated as the rating of the fuel was increased. As marine reactors would tend to be highly rated to reduce their weight per hp this could be serious. It could, however, be overcome by adding enrichment to the fuel, but it must be carefully considered whether to do so was worth the extra cost.

If the excess activity necessary to override the xenon poison was not provided, up to as much as 24 hours must elapse before the reactor could be started after it had once been shut down. The rate at which reactor power could be reduced was also severely limited. The difficulty could be overcome by providing a small steam or diesel engine sufficient to give the ship steerage way at sea and to provide the heat and power requirements in port. In this way the reactor could be worked at constant power continuously, any surplus steam being rejected to the main or a separate atmospheric dump condenser. This would have little effect on the operating cost or capital cost of the ship.

Safety Precautions

As regards safety precautions marine reactors would closely follow shore practice, though the design of the hull might be affected by the provision of several zones of containment between the fission products in the fuel elements and the atmosphere. The reactor compartment could be made completely leak-tight without materially increasing the capital cost.

No hazard from foundering would arise in oceanic waters, although in coastal waters damage to fisheries or contamination of the seashore might occur. The present corrosion rate was high and it might be advisable to specify a fuel of which the rate in sea-water was less than about 0·1 per cent per day. There would be little damage to divers engaged in salvage, although continuous radiological control of those working on the reactor would be necessary. The reactor could also be protected against the effects of grounding and collision. In fact, of the possible causes of fission product dispersal to the atmosphere, perhaps the risk of fire was the greatest. A valuable ultimate safeguard would be to use uranium oxide as a fuel as this did not burn in air.

The Influence of Shipboard Conditions

The reactor and machinery in a ship were subjected to acceleration forces and fluctuating deflections imposed by cargo loading and heavy weather. In the study of the tanker mentioned above, the accelerations due to these causes were assumed to occur simultaneously and no difficulties were found in designing to withstand the resulting forces. It was desirable to design the reactor so that it would remain structurally stable in event of the ship capsizing and to arrange the control rods so that they would function in any position of the ship.

Although graphite-moderated gas-cooled reactors could be used for the economic propulsion of ships requiring 25,000-shaft hp or more, their use at smaller powers did not appear promising. The pressurized-water reactor could be made sufficiently light for the smaller ships, but because it used pure fissile material it was questionable whether it would be economical. A similarly compact reactor could be designed to use an organic liquid, of which the polyphenyls looked the most promising, as moderator and coolant. Up to the present, however, no organic liquid had been found which was stable under irradiation. Very high ratings could be obtained by using a liquid metal, such as sodium, as a coolant, but it reacted violently with water, ignited in air at temperatures above about 150 deg C and became highly reactive on passing through the reactor, so that the whole of the primary circuit must be heavily shielded. Heavy water was a much better moderator than graphite, but the coolant must be physically separated from it, which detracted from good neutron economy.

At present it was not possible, said the authors, to foresee a reactor system which would be economical in smaller ships, but rapid development was taking place in the direction of lower weight per horse power and low capital costs, so that reactors for ships of 20,000-tons capacity and less would become available within ten to twenty years.

* * * *

The development of an advanced form of the Calder Hall type of reactor for use in merchant ships was mentioned recently in a reply to a question in Parliament. The Civil Lord of the Admiralty said that this was one of the most promising possibilities, and work was proceeding at all speed. A considerable programme of work would be necessary before the building of a ship would be practical. He stressed the difference between the requirements of a nuclear submarine and the strictly economic requirements of a merchant ship which 'has to hold its own with conventionally-powered ships'.

New equipment and processes

Mobile oil-processing plant

A mobile test laboratory and transformer oil-processing plant—said to be the first mobile servicing unit of its kind in this country—has now been put into service by the *Manchester Oil Refinery Ltd.*

Designed to carry out the degassing, dehydration, and filtration of insulating oil on site, it is capable of providing the following services:

(1) Filling with new oil large transformers which are delivered to site either gas-filled or under vacuum, with subsequent degassing, dehydration, and filtration to obtain the maximum electrical properties of the oil.

(2) Drying out large transformers by continuous circulation of their insulating oil under high vacuum and at high temperature.

(3) Dehydration and refiltration of oil in existing transformers when required by the condition of the oil.

It is claimed that operations such as the removal from the oil of water which may have accidentally entered the transformer can be effected in very much less than the time usually required, and that the breakdown voltage of the oil can be raised to a figure well in excess of the requirements of BS 148 : 1951.

The processing section of the unit comprises a coarse filter, oil heater, filter press, and spraying tank, and pumps for circulation, vacuum drawing, and delivery. Maximum throughput rate is 1100 gal/hr (5000 l/hr). The unit utilizes both static and dynamic vacuum dehydration concurrently; additionally, a spraying technique still further increases the drying rate. A heater bank is provided to raise the oil temperature to any desired level if there should be large amounts of water present in liquid form which cannot be completely volatilized by simple spraying.

Filter units operating over a wide temperature range are claimed to remove effectively all traces of impurities, such as fibre, metal, or paper, which may contain occluded moisture, and the plant is stated to be so arranged that dried and degassed oil cannot be contaminated by moisture already eliminated.

The vehicle which tows the processing unit is equipped as a mobile laboratory under the control of an experienced chemist, and has facilities for carrying out most of the tests required by BS 148 : 1951.

Polyurethane varnished fabrics

A recent development by *H D Symons & Co Ltd* is the application of polyurethane varnishes to such materials as nylon, 'Terylene', and glass. The varnish film is stated to be extremely tough and flexible and to give the final product exceptional electric strength/stretch characteristics.

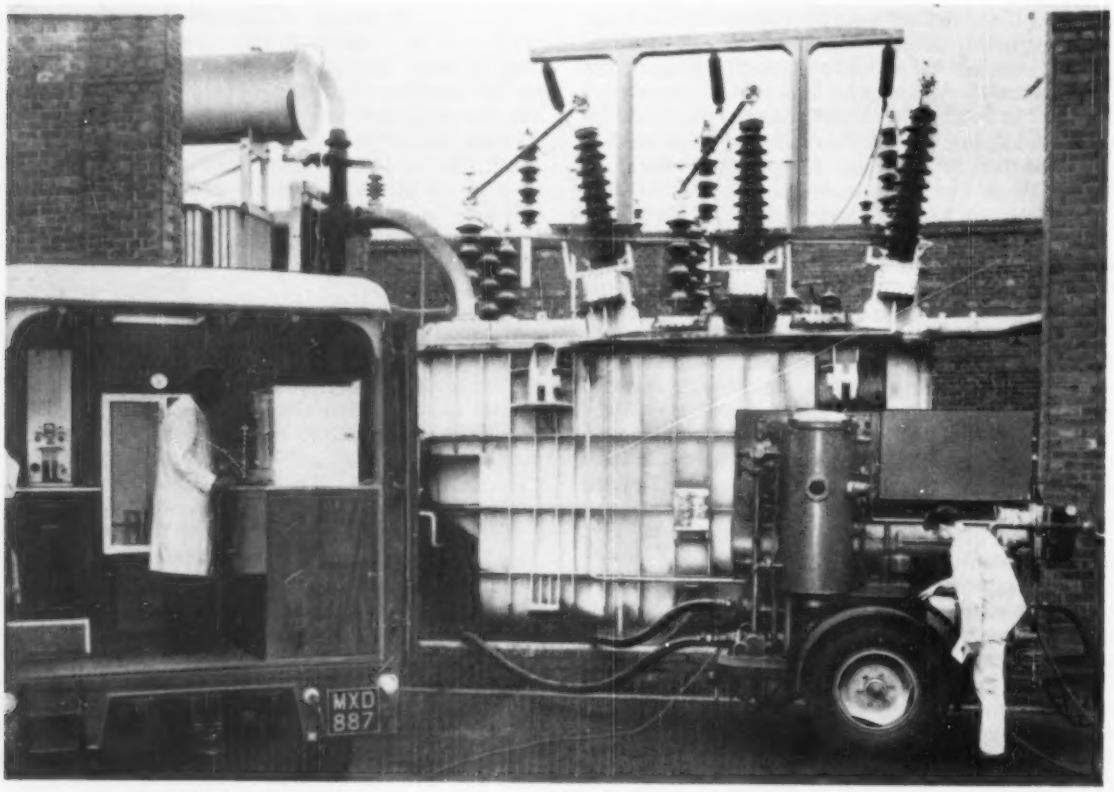
Polyurethane varnishes are not acid, nor do they become acid with age. Among other properties claimed for them are that they are highly resistant to chemicals; that they will withstand temperatures up to class F temperature of 155 deg C; and that their resistance to heat ageing is far better than conventionally varnished fabrics.

The makers feel that there should be a big future for this new material and that they may replace mica tapes in many class A and class B applications. They report that it is already being used on the overhang of large alternator stators.

Polyurethane varnished fabrics are available in straight cut or bias rolls 36 in (91 cm) wide, or as tape in any width in English or metric measure. Materials and thicknesses manufactured up to the present are nylon—4, 5, and 6 mils (0·1, 0·13, and 0·15 mm); 'Terylene' and glass—5 and 6 mils (0·13 and 0·15 mm).

New heat source for faster cooking

Newly introduced by the *General Electric Co Ltd*, and shown for the first time at the International Hotel and Catering Exhibition in London last month, is an infra-red quartz



The new MOR Transformer Oil Servicing Unit carrying out the reconditioning of transformer oil on site. The mobile laboratory (left) *is equipped to carry out a variety of test procedures*

lamp described by its makers as 'a heat source of the future'.

Taking the form of a slim tube 1 ft (30·5 cm) long, it provides an extremely high temperature in 2 to 3 seconds, and so offers marked advantages to hotels and restaurants in the way of faster cooking, a quicker turnover of customers, reduced waiting periods, and a lower labour cost per meal.

There are also many industrial applications where the particular advantages of these lamps for rapid heating and drying can be put to good use.

Since the tubes are made of quartz, their physical size can be considerably reduced as compared with glass. Moreover, the quartz transmits high amounts of radiant energy more easily than glass and has a high resistance to thermal shock. Although the new lamps emit some light, the greater part of the radiant energy is in the form of infra-red rays.

Two ratings are in production: a 500 W size for operation from 100/130 V supplies, and a 1 kW unit for 200/250 V operation. At 115 and 230 V, respectively, a life of 5000 hours is claimed.

The new Exide batteries

Recently announced by *Chloride Batteries Ltd* are two new special types of Exide batteries. The first—known as 6 WXA15ZR—was originally designed to meet the requirements of military vehicles operating in conditions of extreme cold, and one of its unusual features is that it can be artifically heated to ensure an extra high rate of performance in low ambient temperatures.

This unique property derives from its multi-compartment, die-cast aluminium container lined with high-grade hard rubber, which permits the battery to be heated by almost any external means except, of course, the direct use of a naked flame. Furthermore, the heating can be controlled by a thermostat which may be attached to a special moulding in the centre cell connexion.

The exterior of the aluminium container is coated with Epikote epoxy resin to provide both a corrosion-resistant finish and electrical insulation against accidental short-circuits, and handles are cast integrally with the container for ease of lifting.

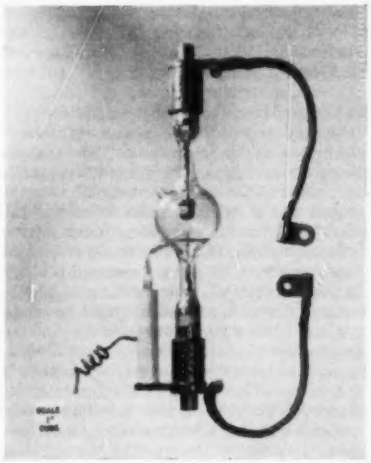
The battery is stated to be capable of very high rate discharges over a wide temperature range. For example, at an electrolyte temperature of 70 deg F (21·1 deg C) it is claimed to discharge at 100 A for 16·5 min to a final voltage of 8·0, while at 0 deg F (−17·8 deg C) it will deal with engine starting demands of the order of 300 A without falling below 8 V.

The Exide 6WXA15ZR measures $6\frac{13}{16}$ in wide by $15\frac{3}{8}$ in long by $8\frac{7}{8}$ in high (17·6 cm by 39·1 cm by 22·5 cm) and weighs approximately 51 lb (23 kg) unfilled or $63\frac{1}{2}$ lb (28·7 kg) filled.

The other new battery is a Silver Exide, type 3-XNFB19ZL, specially designed for the Ferguson model 35 tractor. It has Porvic separators, intercell connexions of the proud pattern, is fitted with special PSV type terminals, and is assembled in a hard rubber container with 'Tractor Battery' moulded on the side panel.

The Ferguson 35 tractor takes two batteries of this type, one of which is exposed, and there is available for its protection a moulded hard rubber cover incorporating a detachable polythene hatch giving access to the vent plugs. Holes are provided for the battery securing bolts, and the cover will, of course, also fit the battery which forms part of the tractor's initial equipment.

The 3-XNFB19ZL is a 6 V battery with a capacity of 129 Ah at the 20-hour rate, and a bench charge rate of 9 A. Overall dimensions, including cover, are $14\frac{1}{2}$ in long, $6\frac{13}{16}$ in wide, and $10\frac{5}{8}$ in high (36·8 cm by 17·6 cm by 25·9 cm) and its weight when charged is 57 lb (26 kg).



The Xenon light source used in the new BTH film projector described below

BTH sound-film projector with Xenon light source

One of the principal limitations of 16-mm sound-film projectors—that of inadequate screen illumination—has hitherto restricted their use to small halls. A great deal of research has been devoted to improving the conventional tungsten filament lamp and to investigating alternative light sources, and now the *British Thomson-Houston Co Ltd*, who were the pioneers in the field of 16-mm sound-film projectors, have produced the new Model 450-X which uses a Mazda Xenon lamp.

This lamp opens up new possibilities in screen illumination. It provides a compact, high intensity light source, and since the most brilliant section of the source is rectangular, it has the special advantage of horizontal operation.

The electrodes of the Mazda Type XE/D lamp (anode, cathode, and ignitor) are enclosed in a gas-filled envelope of fused silicon of almost optical quality, and sufficiently strong to need no protective casing. The light source is compact and the emitted light covers the whole spectrum from ultra-violet to infra-red. The 'colour' is closely akin to sunlight and therefore yields greatly improved reproduction of colour films. Its colour temperature is approximately 5600° K.

No 'warming-up' period is required; the lamp strikes up to full brilliance immediately it is switched on. With a terminal voltage of 28/30 V dc and a maximum current of 100 A, it is rated at 2000 W (nominal).

The projector itself is a logical development of the BTH Model 450, with the components rearranged to suit the new form of lamphouse, and the sound-head redesigned to reproduce either optical or magnetic sound tracks. To take advantage of the greatly increased light output, a 'Cinemascope' attachment can be mounted in front of the projector lens and swung aside when not in use.

Under normal conditions using a 2-in (5-cm) f 1·5 projection lens, a total screen illumination of 1000 lumens is obtained. This is equivalent to about four times the output of the modern 750 W tungsten filament lamp; in other words, the new Xenon lamp will give a picture of twice the width and twice the height for the same brilliance.

New Hurseal radiators

An intermediate size in the range of oil-filled electric panel safety radiators has recently been introduced by *Hurseal Ltd*. Intended for rooms where a 1·5 kW radiator is a little too much and a 1 kW not quite enough, the new TV $1\frac{1}{4}$ model has a loading of 1·25 kW and is suitable for 'average' rooms of about 1000 cu ft (28 m³). Its total heating surface of 19·3 sq ft (1·8 m²) is some 4·5 sq ft (0·4 m²) larger than the 1 kW model.

The new TV $1\frac{1}{2}$ radiator is portable and fitted with feet for floor standing, but can be supplied with castors as an optional extra. Dimensions are 26 in high, 52 in long, and $\frac{3}{4}$ in wide (66 cm by 132 cm by 1·9 cm) and colours available include the standard Hurseal bronze or cream, white, gold, sky blue, and eau-de-nil.

Another new model is the S75—a 3-column lightweight radiator of 0·75 kW loading. It is only $10\frac{7}{8}$ in (27·6 cm) high and intended primarily for wall fitting under windows which reach almost to floor level, but is equally suitable for installation under window seats and work benches, or as a special installation beneath pews and stalls in churches and halls where additional or local heating may be required. The overall length is 27 in (69 cm) and width $5\frac{1}{2}$ in (14 cm), giving a heating surface of 13·5 sq ft (1·25 m²), and this model is also available in the range of colours listed for the TV $1\frac{1}{4}$.

Prismatic bulkhead fitting

A new prismatic bulkhead fitting for surface or partially recessed mounting has recently been introduced by the *General Electric Co Ltd*. The body is constructed of rust-proofed, stove-enamelled 18-SWG pressed steel, and the white-enamelled reflector carrying the porcelain BC lampholder is detachable for ease of wiring.

Other facilities include the provision of glass-braided sleeving for the protection of 'through' cables; two earthing terminals—one on the body and one on the internal reflector; $\frac{3}{4}$ in (19 mm) knockout on each side and at the back, suitable for BS fixing, or alternative fixing by two holes at 4 in (102 mm) centres.

The unit, which houses one 100 W Osram lamp, is supplied with either clear or obscured prismatic glass, sealed to the body by a 'Neoprene' gasket.

Book Reviews

An Introduction to Semiconductors *By W C Dunlap Jr.* $9\frac{1}{4} \times 5\frac{3}{4}$ *in* (235 × 146 *mm*). *Pp xxi* + 417. *Illustrated. Index.* (*New York: John Wiley; London: Chapman & Hall*, 1957.) Price 94s net.

For the engineer who wishes to back his practical use of semiconductors with sound information on the theoretical side of the subject, and on the part of solid-state physics which covers it, this is an excellent book. It is also valuable to the senior engineering student who is preparing to specialize in semiconductors and their uses.

The chapters include: Crystals and Their Structure; Theory of the Solid State; Imperfections in Crystals; Electron Theory of Metals and Semiconductors; Contact and Surface Properties of Semiconductors; Properties of p-n Junctions; Measurements on Semiconductors; Methods of Preparing Semiconductors; Properties of Elemental Semiconductors; Rectifiers; Transistors; and on the use of semiconductors in special applications such as photo-cells, thermistors, Hall effect, etc.

The book contains very little extensive mathematical treatment, and can be read straight through by the engineer who wishes for a qualitative rather than a quantitative treatment of the subject.

Transistors and other crystal valves do not dominate the book, in fact the applications of semiconductors only occupy the last quarter of it.

J H J

Applied Electricity. *By A T Starr.* $8\frac{3}{4} \times 5\frac{1}{2}$ *in* (222 × 140 *mm*). *Pp x* + 502. *Illustrated. Index.* (*London: Sir Isaac Pitman & Sons*, 1957.) Price 25s net.

The preface states that this new book on Applied Electricity has been written for the syllabus in this subject in the Part I Examination for the BSc (Engineering) degree of the University of London. It would, however, appear that the author intended the book for the syllabus of the Old Regulations. In consequence, the treatment is more extensive and comprehensive than is required for the new Revised Regulations. This is unfortunate, for it is clear the author had in view the preparation of an examination textbook and the present scope may tend to discourage potential readers.

The fourteen chapters of the book deal successively with the direct current circuit, electrostatics, magnetism, electromagnetism, MKS units, chemical and thermal effects of currents, direct-current machines, alternating current, polyphase current, transformers, measurements and measuring instruments, alternating-current machines, illumination and electronics.

Although the treatment is academic, as required for the purpose the author had in view, the text contains numerous fully worked numerical examples to bring out the application of the theoretical process to particular problems. These will be of considerable help to students preparing for examinations. In addition, there are 192 examples for the reader to solve, with answers in an appendix at the end of the book.

The book is printed on good quality paper with the style and format distinctive of this publisher. Although there is nothing original in the text, which follows the traditional pattern, it is so written that it is likely to appeal to students and thus it should have a ready sale.

P F SOPER

Vector Analysis. *By Louis Brand.* $9\frac{1}{4} \times 6$ *in* (235 × 152 *mm*). *Pp xiii* + 282. *Index.* (*New York: John Wiley; London: Chapman & Hall*, 1957.) Price 48s net.

In the preface to this book the author says, 'The day is not far distant when vector algebra will be introduced in analytic geometry, thus giving the student the double advantage of an early introduction to the subject and a welcome relief from a multiplicity of formulas to be memorized'. Later on he continues, 'And then that tremendous step from two to three dimensions which usually occurs so late in the course that the student misses it altogether need never be taken at all. For we *start* in three dimensions, the world we actually live in. . . .' And there is the essence of the underlying motive of this book which presents the fundamental theory of the subject, not only for College students but also for those mathematicians, physicists, and engineers who are not well versed in it.

The ground covered is well exhibited by the chapter headings which are: vector algebra, line vectors, vector functions of one variable, differential invariants, integral theorems, dynamics, fluid mechanics, electrodynamics, and vector spaces. Problems are set in the book and answers are provided. Numerous examples are worked out in the text itself and the applications given are of practical significance as well as calling for thoughtful examination.

The book is one that can well be recommended and it is a very acceptable addition to the author's three previous volumes on Advanced Calculus, Vector and Tensor Analysis, and Vectorial Mechanics, respectively.

The Numerical Solution of Two-Point Boundary Problems in Ordinary Differential Equations. *By L. Fox.* $9\frac{1}{2} \times 6$ *in* (241 × 152 *mm*). *Pp xi* + 371. *Index.* (*London: Oxford University Press*, 1957.) Price 60s net.

A boundary problem in ordinary differential equations is defined by the author as one in which all the necessary associated prescribed conditions are given at more than one point in the range of the independent variable; the conditions are called boundary conditions and the differential system is of the boundary-value type. It is with such problems and systems that the present book is concerned, giving both methods and numerical techniques and including most of those that are suitable for pencil-and-paper and desk-machine computation. Thus, and in particular, the book is especially valuable to those workers to whom the much larger and more expensive automatic high-speed computer is not available, although the methods set out are adaptable to such types of machines.

The main part of the book describes various boundary-value methods for differential systems of orders one to four, including eigenvalue type of problems. Both linear and non-linear cases are dealt with and special attention is given to the proper numerical treatment of the various possible types of boundary conditions. The precision of the solutions obtained is discussed in a separate chapter.

Following a brief introductory chapter the author discusses the following: finite differences and finite-difference equations, the solution of algebraic equations, second-order equations, first-order equations, equations of higher orders, eigenvalue problems, initial-value techniques for boundary-value problems, accuracy and precision of boundary-value methods, and miscellaneous methods and comments. Additional notes and a bibliography end each chapter and an excellent index concludes the work.

Apart from the mathematical techniques obviously denoted by the title, the author employs those of matrices, relaxation, iteration, and Taylor series, as aids to the solutions of the problems discussed. There are many worked-out examples in the book, designed not only to illustrate the methods described but also to assist computation.

The book has been written for those engaged in practical computation and for the student seeking a career in that field. There is no doubt whatever of its eminent suitability for both these purposes, and without reserve we recommend this masterly presentation of an important branch of applied mathematics which is claiming ever-increasing attention. The printing and general format are, of course, unexcelled. The book belongs to the publisher's series of Monographs on Numerical Analysis.

S AUSTEN STIGANT

Electrical Engineering Circuits. *By Hugh Hildreth Skilling.* $9\frac{1}{4} \times 6$ *in* (235 × 152 *mm*). *Pp ix* + 724. *Index.* (*New York: John Wiley; London: Chapman & Hall*, 1957.) Price 70s net.

To a large extent the study of electrical engineering has up to the present time followed the traditional pattern set by both civil and mechanical engineering courses. Once the elementary stage has been passed the subject matter has been divided up into a number of watertight compartments. These divisions have each acquired an examination status with recognizable titles such as Electrical Power, Electrical Machines, Electrical Measurements, Electronics, Telecommunications, and High Voltage Engineering. In consequence of this division there is a considerable overlap of syllabuses, a lack of coherence, and often a failure to present a broad picture with a corresponding narrowness of outlook in the treatment. As a result, almost all syllabuses are grossly overloaded and it is generally agreed that this is a very undesirable state of affairs. Fortunately, a school of thought has been slowly developing which recommends a re-examination of the whole structure of the curricula of electrical engineering courses. In particular, it is recommended that material common to all

subjects and thus fundamental to all students should receive priority. An example of this is electrical circuit theory. Secondly, it recommends a generalization of ideas and concepts. An example of this is the two-axis theory in electrical machines. Thirdly, it urges the deletion from syllabuses of all unnecessary and factual material, since such matter does not provide any lasting benefit to the student. An example of this arises with detailed construction features and special applications. Lastly, it urges that syllabuses should only deal with principles of the subject and how these principles are applied and used.

These considerations are important when reading this new book on Electrical Engineering Circuits, for this is clearly an attempt to fulfil some of the foregoing decidera. In particular, it is not confined to one branch of electrical engineering and it does attempt to generalize the treatment.

The contents of the 21 chapters of the book deal successively with the elementary theory of alternating currents, the principles of the steady state analysis of electrical circuits, network transformation, resonance, graphical methods, loci diagrams, network equations (branch, mesh and nodal), elimination of nodes or loops, duality, matrix methods, network theory, networks with mutual inductance, coupled circuits and transformers, circuits with non-linear elements, Fourier analysis, numerical analysis, Fourier series and Fourier integral, transient response and the complex frequency plane, Laplace transformation, two-terminal-pair networks, general network functions, electric filters, and finally balanced and unbalanced three-phase circuits.

There are 362 line diagrams, and 431 problems for the reader to solve. The answer to each fifth problem only is given in an appendix at the end of the book. The answers to all the problems should be provided in any future edition, as it is of considerable assistance to conscientious students who work on their own initiative. An appendix at the end of the book gives a bibliography of 51 references for further reading on specific parts of the text.

The author has presented his reader with a coherent treatment of electrical circuits from the elementary to the advanced conceptions applicable to all branches of electrical engineering. He has wisely confined attention to lumped circuits, and a study of the book cannot but fail to give readers a broad and general outlook. The author has also included a number of fully worked numerical problems in the subject of the text.

This readable book is printed on good quality paper with an attractive format and a reasonable binding. It deserves to be on the bookshelf of all students of electrical engineering, as it has a refreshing outlook and is not a rehash of standard traditional subject matter.

P F SOPER

Vector Spaces and Matrices. *By Robert M Thrall and Leonard Tornheim.* $9\frac{1}{4} \times 6$ *in* (235 × 152 *mm*). *Pp xii* + 318. *Index.* (*New York: John Wiley; London: Chapman & Hall*, 1957.) Price 54s net.

This admirable book is one that, at the very least, should be known about by all those who teach matrix theory or who use matrices as a mathematical tool in the development of other branches of science and technology. In writing it the authors have employed an interesting dual method of approach which they have called the concrete approach via matrices and the intrinsic or axiomatic approach via linear transformations. The result of this parallel presentation is that, in their own words, 'It introduces the student to the elegance and power of mathematical reasoning based on a set of axioms and helps bridge the gap that lies between the pre-eminence of problem solving found in most elementary undergraduate courses and the axiomatic approach that characterizes much modern research in mathematics'. This is both rational and illuminating especially as the treatment has been framed to develop an understanding and conceptual grasp of the subject rather than merely to exhibit the mechanics of manipulation.

Chapters 1 and 2 introduce the concepts of vector space, linear transformation, and matrices, whilst Chapter 3 shows how these concepts are applied to the solution of systems of linear equations. Chapter 4 gives a self-contained development of the theory of determinants, and Chapter 5, on equivalence relations and canonical forms, formulates the general concept of invariance and includes a brief introduction to the theory of similarity. Chapters 6 and 7, on functions of vectors and on orthogonal and unitary equivalence respectively, cover the more usual bilinear and quadratic forms and orthogonal equivalences.

The remaining four chapters of the book are of a more advanced character and the level of exposition is correspondingly higher. Chapter 8 is on the structure of polynomial rings and it gives the standard theory of polynomials in one indeterminate and proceeds to develop the general theory of simple algebraic extensions of a field. Chapter 9, on the equivalence of matrices over a ring, presents the standard canonical forms for matrices with integral or with polynomial elements, applying the results to differential equations with constant coefficients and to finitely generated abelian groups to obtain the fundamental theorem. Chapter 10 relates to similarity of matrices and it gives the similarity theory with the usual canonical forms and includes applications to geometry and to differential equations. Chapter 11 is on linear inequalities, and it presents a brief introduction to this important topic which hitherto has been neglected in elementary texts on matrix theory. There are two appendices on mathematical induction, and on relations and mapping, a bibliography, a glossary of special symbols, and the usual index. Exercises are set throughout the book but no answers are provided.

Matrix theory is used so extensively today and it has been found to be such a valuable asset in widely diverse fields of application, that the present book should find ready acceptance. It is clearly and logically written and the only complaint (if there be a valid one) that might conceivably arise is that the language is so very much in the formal style of the professional mathematician, that the engineer and physicist for whom the book is, we imagine, in some substantial measure intended, may perhaps be discouraged from giving the work the close study it warrants. Printing, format, and general production of the book well support the publishers' reputation for first-class work.

S AUSTEN STIGANT

Transistor Circuit Engineering. *Edited by R F Shea.* $9\frac{1}{4} \times 6$ *in* (235 × 152 *mm*). *Pp xx* + 468. *Illustrated. Bibliography.* (*New York: John Wiley; London: Chapman & Hall*, 1957.) Price 96s net.

This book is a thoroughly practical and comprehensive work which should be of considerable value to the design engineer who wishes to use transistors in a wide range of electronic devices, and to use them in a way which accords with the best present-day practice. Many of the transistor circuits which are published in other places are quite practical, but they are not always the best ones to use in given circumstances. In this book, however, the reader is shown how to avoid this state of affairs, by being provided with all the necessary data to link basic transistor theory with the best circuit practice.

Chapters are included on Equivalent Circuits; Audio Amplifiers; dc Amplifiers; Tuned Amplifiers; Video Amplifiers; Oscillators; Modulation; Transient Response; and also on completely 'transistorized' communication systems.

Particularly useful is a chapter on Bias and Its Stabilization, which shows that if the transistor circuits are biased correctly they are not nearly so temperature-dependent as many engineers believe them to be.

The eight authors and the editor are all members of the staff of the General Electric Co of America, and it is likely that this work will become a standard one on the subject, if it is revised in the light of developments which have taken place by the time that a new edition is called for.

A bibliography down to and including 1956 is provided.

J H J

Elementary Theory of Angular Momentum. *By M E Rose.* $9\frac{1}{4} \times 6$ *in* (235 × 152 *mm*). *Pp x* + 248. *Index.* (*New York: John Wiley; London: Chapman & Hall*, 1957.) Price 80s net.

In the context of this book angular momentum has reference to the rotation of the fundamental particles of nuclear and atomic physics. The theory has become increasingly important in the development of physical theories of nuclear and atomic structure by reason of improvements in experimental techniques of measuring angular distributions in nuclear reactions, although, as the book shows, it can be applied very advantageously to the formulation and solution of problems associated with the static magnetic and electric nuclear moments, which are coupled to the electric and magnetic fields arising from surrounding charges.

The first chapter is a review of basic principles in which such discussion of operators and their matrix representations are presented as is pertinent for the sequel. The second chapter discusses the angular momentum operators, defining these and giving a physical interpretation of angular momentum. The remaining four chapters comprising Part A carry the development through the introduction of the coupling coefficients for vector addition (C-coefficients), the transformation properties of the angular momentum wave functions under rotations of the coordinate axes, irreducible tensors, and Racah coefficients. The applications

presented in the six chapters of Part B deal with static moments of systems composed of charged particles and elementary magnetic dipoles, particles of intrinsic spin ½ and 1, oriented nuclei including angular correlation in cascade disintegrations as well as angular distributions and changes in total cross sections in low-temperature experiments, coupling schemes in nuclear reactions, and wave functions for systems of identical particles.

There are appendices on Clebsch-Gordan and Racah coefficients, the rotation matrices, and the spherical harmonics. Author and subject indexes complete the book.

The author points out that the theory of angular momentum is a highly formal one, its principal ingredients being certain parts of group theory and tensor algebra. These mathematical tools are thus employed in the text as are also matrices, spinors, and various operators.

The book is intended for physicists and for those with a graduate-course knowledge of quantum mechanics. In particular it has been devised to increase the usefulness of angular momentum theory as a tool to experimentalists, and its clarity of exposition should leave no doubt of its value in this respect. The author is Chief Physicist at Oak Ridge National Laboratory, USA, and all the authority of his experience in that important post is evident in the present work.

The Physics of Electrical Contacts. *By F Llewellyn Jones.* $9\frac{1}{4} \times 5\frac{1}{2}$ *in* (248 × 140 *mm*). *Pp* x + 219. *Illustrated. Index.* (*London: Oxford University Press*, 1957.) Price 35s net.

The ultimate control of any electrical circuit is the switching device, by means of which the circuit can be closed or opened. The mechanical closing or opening of metal contacts is applied over an immense variety of equipment, from the relay contacts in communication installations, through the contactors used widely for plant control, to the very-high power circuit-breaker. The duties required of the contacts are correspondingly varied—those in communication circuits handle very little power indeed, but must remain efficient for very long periods and over many operations. In contactors, there is a requirement for long life and many operations, but with the added complication of arc currents which cause serious burning at the electrodes and the arc itself which must be controlled by arc chutes. The high-power circuit-breaker has to deal with fault currents of many kiloamperes, and the electrodes are fitted with arcing tips to resist erosion, although the normal current is carried through contacts of conventional materials.

With such a wide range of application, it is understandable that developments in each of the three categories mentioned have tended to proceed empirically, and apparently without much of common interest. The engineers have achieved working solutions in each field, but it cannot be denied that practice has always been ahead of fundamental knowledge of the physical phenomena. The reason for this lies in the great difficulty of controlling all the physical factors involved, the fact that sparking and arcing are essentially transient and unstable phenomena in themselves, and the difficulty and expense of any research at high power values.

Whatever the nature of the contacts and the medium in which they are immersed, the common feature in all operations is that there is one point on the surface at which electrical continuity is finally established or destroyed, and it is only subsequent to this that external conditions become the major design consideration.

Even with communication equipment, which represents the most convenient conditions for research, control of all the factors involved is a major experimental difficulty. Much work has been done in this field, and the book by Holm is well known to designers.

Professor Llewellyn Jones and his colleagues at Swansea have, for a number of years, been investigating phenomena occurring at contact separation, and this has resulted in the present book giving a review of previous work, and including the results of their own work to date which stands out as a most important series of contributions to the subject. Although the author states that this is 'in no sense a handbook for the design of contacts for particular purposes', the emphasis being on the basic physics important to all contacts, the fact that it concentrates upon the final stages of breaking electrical continuity means that it is of material value to all engaged in design or research on contact phenomena. It is from this stage that theory applicable to given conditions has to be developed. Its initial appeal will be to the relay engineer, but on studying it, the power engineer will find many points to stimulate his thinking.

The early chapters give an excellent account of fine transfer as a source of contact deformation when there may be no electrical discharge involved. Chapters 5 to 7 contain an account of original work on the molten metal bridges that are formed in the final stage of interruption, and the work is outstanding in technique and analysis. Very useful comment and summaries are given at the end of each section. The study of the molten bridges was greatly advanced by the use of radioactive isotopes to observe transfer in both directions. It is shown that the Thomson shift and Kohler mechanism fail to explain the observed transfer, but the theory of Buhl, that transfer occurs by the movement of charged metal droplets in the electric field, is 'consistent with the experimental data and can explain the observations qualitatively'.

The final chapters on Erosion, Discharge Phenomena, and Surface Films, represent the first steps in extending basic knowledge to fields of great practical interest, and many important researches could be based on the opinions expressed. In a summary of self-quenching by electron attachment to water molecules, it is of interest to mention that water vapour not only aids in quenching, but is known to increase the breakdown voltage of a gap by a similar process.

Chapter 6, on the properties of metals at high temperatures, while it arose from the study of bridges, describes techniques which greatly increase the scope for the study of metal properties in the molten state, and represents not the least of what the book has to offer.

The book is produced in the form of the publisher's monograph series which is now well known, and the author has achieved that clarity of style so essential to dealing with a complex subject. It is by no means easy reading for an engineer, but the time devoted to careful study will be amply rewarded. Everyone will look forward to further contributions to the subject from this active research group at Swansea.

F M BRUCE

Circuit Theory and Design. *By John L Stewart.* $9\frac{1}{4} \times 6$ *in* (235 × 152 *mm*). *Pp xiv* + 480. *Illustrated. Index.* (*London: Chapman & Hall*, 1956.) Price 76s net.

This book is devoted primarily to the synthesis and design of networks both with and without vacuum tubes. The synthesis is of two kinds: (*a*) function synthesis, involving the derivation of a relatively abstract mathematical function that is realizable with a network and that is desirable from some point of view, and (*b*) network synthesis, which is concerned with establishing a physical circuit that realizes some given function. The types of networks studied in the book are frequency-dependent and mostly those that are linear with time-invariable lumped parameters, the governing equations being linear integrodifferential with constant coefficients. Thus, all variables have constant multipliers, the variables as well as their derivatives and integrals never appear to powers other than the first, and products of variables do not appear.

The technique forming the central feature of the book is the pole-zero design method which, although having been in use for several years, is by no means so familiar to the general run of system designers as it should be, and it is the aim of this work to remedy that state of affairs.

The first six chapters relate to matters which broadly can be said to apply to most types of networks (with the provisos mentioned above). They cover circuit analysis, poles and zeros of functions and networks, synthesis and numerical procedures, gain functions, and modern synthesis. The remainder of the work covers the network aspects of image parameters, filters, vacuum tubes, low-pass and band-pass amplifiers, feedback amplifiers, oscillators, and servo mechanism functions.

The book is intended chiefly for college undergraduates and graduates, and we believe they are considerably indebted to the author for having undertaken so necessary a study of the theory and applications of the pole-zero method. The book will probably be a standard work on the subject for quite a long time.

Man and Automation. *By L Landon Goodman.* $7\frac{1}{8} \times 4\frac{3}{4}$ *in* (180 × 111 *mm*). *Pp* 286. *Illustrated. Index.* (*London: Penguin Books Ltd*, 1957.) Price 4s net.

Among the reasons for the growth of industry to its present-day proportions has been the fact that engineers have always, as part of their job, constantly sought quicker and better means of production.

Engineers concerned with manufacture and production tend sometimes to be unconvinced about 'automation', notwithstanding that the mainspring of industrial progress has been the continued application of better and faster processes and that (according to the author) automation embodies a new concept only in so far as it extracts four components—mechanical handling,

processing, sensing, and control—from a host of others to make it possible.

However, increased demand has greatly stimulated the need for improved methods and full order books have made them financially possible, while developments, particularly in the fields of electronics and automatic control, have made projects feasible which would have been impossible only a few years ago.

Automation, however, is not just a technical matter. Obviously the increased utilisation of machines poses quite a number of social and economic problems, from the re-employment of labour displaced by the machines on one hand to the training of the increased technical staff to operate the plant on the other.

Automation has thus become a subject of great interest to the layman as well as to the practising engineer, and this book should appeal to both. It is divided into two sections. The first deals, in eight chapters, with technical aspects, and after giving a general outline of the subject, goes on to describe how automation is being applied in many spheres, from machine tools (which are the heart of the system) and are dealt with in the various forms of transfer machines, and with analogue and digital computer control, on to data processing, process control, and automation in industry and commerce.

The second half of the book is perhaps the more important as it is concerned with social, economic, and kindred aspects. Successive chapters are concerned with labour and automation, redundancy, the impact of automation on the work itself, on trade unions, and on management. It also deals with staff training, and many other points.

The author is, of course, Industrial Specialist with the British Electrical Development Association and as such is in intimate contact with a wide section of industry and with the latest production methods. He therefore writes with the authority of first-hand experience of his subject plus complete independence of any particular manufacturer.

The book has the further advantage that it is written primarily for the layman and is thus easier to read than a technical textbook, but without losing any of the value and authority of its information.

Mathematics for Science and Engineering. *By Philip L Alger.* $9\frac{1}{4} \times 6$ *in* (235 × 152 *mm*). *Pp xi* + 360. *Index.* (*London: McGraw-Hill*, 1957.) Price 41s 6d net.

This book is a complete revision of C P Steinmetz' Engineering Mathematics which ran to three editions over the years 1911–1917 and which, in its day, provided as sound a text of its kind as could be found anywhere. The present reviewer is a fortunate possessor of a collection of Steinmetz' books and he well remembers the keen pleasure derived from the acquisition of each successive addition. Mr Alger's new book was therefore received with exceptional interest and perhaps with some little background fear that an idol's work might so be 'arranged' or 'modernized' as to be unrecognizable. In the event that has proved not to be the case and for this, in quite some considerable measure, we can probably thank the lucky circumstances of Mr. Alger's close association with Steinmetz and his methods. 'In fact, the present book follows the plan of the earlier one quite closely and incorporates about half of the original material.'

There are fourteen chapters in the new book and, apart from rearrangements, the substance of the first seven is really the same as in Engineering Mathematics. The new sections in these chapters are on interpolation, prime numbers, rules for division, the slide rule, determinants, the conic sections, Simpson's rules, the Fibonacci series, and the unit function. There are four new chapters relating respectively to the calculus, differential equations, probability, and electric circuit theory. The remaining three chapters are on functions, trigonometric series, and maxima and minima and follow the Steinmetz original except in an up-to-date and much condensed form. New and more extensive appendices are now given and problems follow each chapter, with the answers in a supplement. There is also a bibliography at the end of each chapter.

In the preface the author says 'I have taken especial care to preserve the clear explanation of complex quantities . . . and to show their usefulness in developing equivalent circuits to represent all sorts of physical phenomena. In this way, the book provides a bridge between the original ideas of Dr Steinmetz and those of his modern counterpart, Gabriel Kron, whose tensor theory (a generalization of complex number theory) employs such circuits as mathematical models in the ready solution of problems of great variety and immense complexity with the aid of electronic digital computers.' Chapter fourteen in particular is devoted to this latter theme. It speaks well for Mr Alger's perception that he has recognized so well the genius of Gabriel Kron and no higher tribute could be paid to the latter than by linking his name with that of the great Steinmetz of immortal memory.

Mr Alger has already rendered high service to the engineering community by other books and numerous papers and we are now still further indebted to him for the present work which should be in the hands of all those having any kind of interest in engineering mathematics. It is the sort of book that engineers will think first of consulting for most of their mathematical problems. Printer and publisher have well collaborated to produce a book which is easy on the eye and in an attractive format.

S AUSTEN STIGANT

Introduction to Operations Research. *By C W Churchman, R L Ackoff, and E L Arnoff.* $9\frac{1}{2} \times 6$ *in* (241 × 152 *mm*). *Pp x* + 645. *Index.* (*New York: John Wiley; London: Chapman & Hall*, 1957.) Price 96s net.

Operations research (OR) is given the tentative working definition in this book as follows: 'O.R. is the application of scientific methods, techniques, and tools to problems involving the operations of a system so as to provide those in control of the system with optimum solutions to the problems'. The major phases of a OR project are typically: (1) formulating the problem; (2) constructing a mathematical model of the system to be studied; (3) deriving a solution from the model; (4) testing the model and the solution; (5) establishing controls over the solution; and (6) putting the solution to work. These, then, are the features with which the book is chiefly concerned and they are discussed in considerable detail.

The expositions provided in the book are supplemented by case studies, these being concerned mainly with marketing, production, organization, and a variety of problems connected with company business and management. The kernel of OR is, as might be supposed, the mathematical model, and of the ten parts of the book no less than six are devoted to this phase of the subject, for which, however, no higher mathematics is required than elementary calculus and probability theory.

While it does not follow that every problem arising in commerce and industry would find a wholly satisfactory solution in OR there is little doubt that the application of the principles and methods set out in this book would result in at least a much better appreciation and assessment of all the factors involved, and provide a direct pointer to improvement. In a large proportion of cases the methods can clearly achieve the desired results providing, of course, the basic data required for setting up the mathematical models are available.

This is an excellent introductory study to OR and one that can well be recommended.

Receiving Aerial Systems. *By I A Davidson.* $7\frac{1}{2} \times 4\frac{3}{4}$ *in* (190 × 120 *mm*). *Pp viii* + 152. *Illustrated. Index.* (*London: Heywood*, 1957.) Price 21s net.

This book describes and discusses the technical and practical problems which are associated with aerials used for radio and television reception. Transmission and telecommunication systems do not come within the scope of this book, nor does the operation of more than one receiver from a single aerial as this is a separate subject associated with the design of rf circuits.

The questions which are often asked, Why is an aerial necessary? and, what is just as important, Why do they have to be well designed, both electrically and mechanically? are clearly answered, and there is a discussion of the impedance gain and directional properties and the use of these factors as an aid for the rejection of interference such as ghost signals and aircraft flutter.

The all-important half-wave dipole and parasitic rod, which are the basic components of the Yagi type aerials, and which constitute a very large proportion of the aerials in use for vhf and television reception, are fully covered and there are a number of examples of polar diagrams for single and multi-channel aerials.

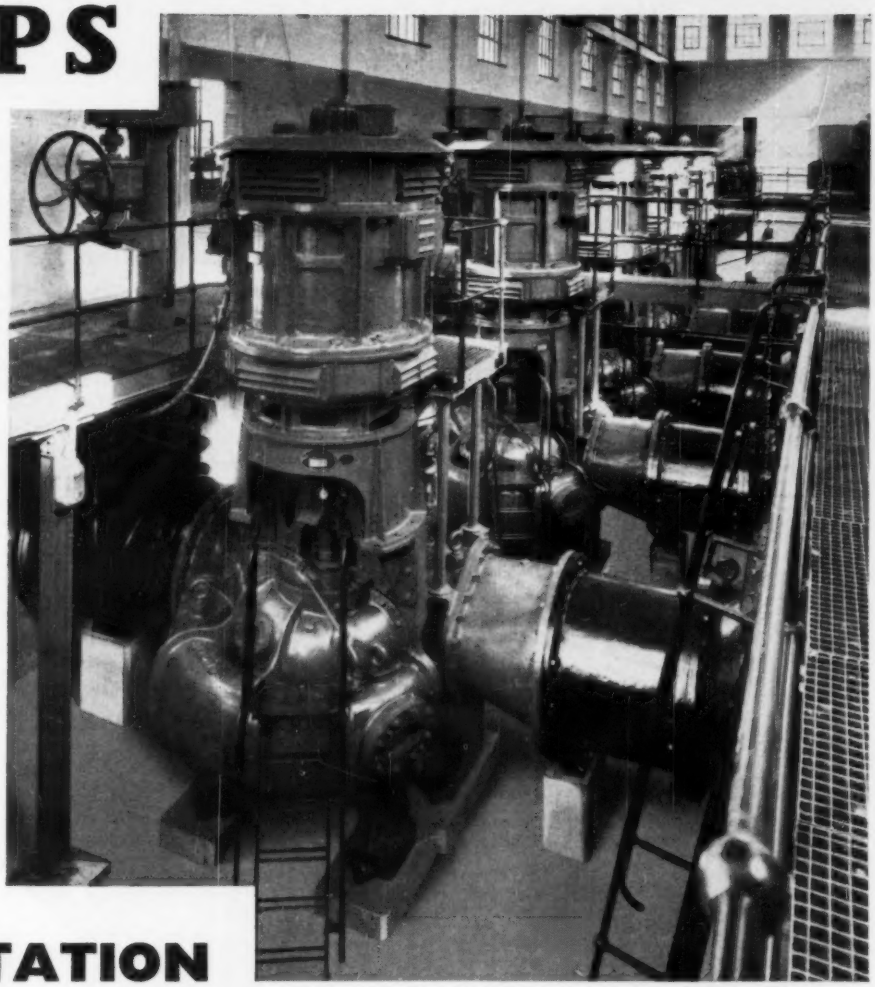
Of particular interest to the installation and service engineer will be the sections dealing with the selection of the right types of aerial for each particular case, the characteristics of transmission lines, how the chosen feeder can affect the type of aerial to be used, attenuation of cables, matching of aerial and feeder in order to obtain maximum signal strength output, vhf accessories, methods of fixing and the stresses and strains which act on aerials, rods and fixing accessories.

The final chapter gives an account of the work which the manufacturers undertake in order to obtain reliable measurements of the performance of aerials and which forms the basis of the data issued to users.

Index to Advertisers

	Page
Allen, W. H., Sons & Co., Ltd.	1
Allen West & Co., Ltd.	2
Arrol, Sir William, & Co., Ltd.	3
Babcock & Wilcox, Ltd.	7
Belliss & Morcom Ltd.	4
Berry's Electric Ltd.	5
Bolton, Thomas, & Sons, Ltd.	9
Bray, George, & Co., Ltd.	6
British Insulated Callender's Cables Ltd.	11
British Thomson-Houston Co., Ltd., The	8
Brookhirst Switchgear Ltd.	12
Brush Electrical Engineering Co., Ltd.	10
Bryce Electric Construction Co., Ltd.	13
Bushing Co., Ltd., The	14
Chloride Batteries Ltd.	9
D.P. Battery Co., Ltd., The	16
Doulton Industrial Porcelains Ltd.	15
Dubilier Condenser Co. (1925), Ltd.	18
Electric Furnace Co., Ltd.	19
Electrical Energy	20
Electrical Industries Benevolent Association, The	20
English Electric Co., Ltd., The	17
Erskine, Heap & Co., Ltd.	21
Ferranti Ltd.	23
General Electric Co., Ltd., The	26, 27
Hackbridge & Hewittic Electric Co., Ltd.	22
Heatrae Ltd.	25
Heenan & Froude Ltd.	16
Henley's, W. T., Telegraph Works Co., Ltd.	24
Hick Hargreaves & Co., Ltd.	28
Jackson Electric Stove Co., Ltd., The	29
Lincoln Electric Co., Ltd.	30
M. & C. Switchgear Ltd.	31
M K Electric Ltd.	32
Mather & Platt Ltd.	34
Mawdsley's Ltd.	33
Metropolitan-Vickers Electrical Co., Ltd.	35
Micanite & Insulators Co., Ltd., The	37
Mirrlees Watson Co., Ltd., The	28
Nalder Bros. & Thompson Ltd.	36
Newton Bros. (Derby) Ltd.	38
P. & B. Engineering Co., Ltd., The	39
Parsons, C. A., & Co., Ltd.	41
Permali Ltd.	42
Pinchin, Johnson & Co.	43
Pitman, Sir Isaac, & Sons, Ltd.	20
Premier Cooler & Engineering Co., Ltd., The	38
Record Electrical Co., Ltd., The	45
Reyrolle, A., & Co., Ltd.	44
Richardsons Westgarth (Hartlepool) Ltd.	46
Sangamo Weston Ltd.	47
Simplex Electric Co., Ltd.	48
Smith, Frederick, & Co.	49
Spencer Wire Co., Ltd., The	40
Sterling Varnish Co., Ltd.	50
Stewarts & Lloyds Ltd.	51
Symons, H. D., & Co., Ltd.	52
Thomas, Richard, & Baldwins Ltd.	53
Weir, G. & J., Ltd.	54
Wiggin, Henry, & Co., Ltd.	55
Yorkshire Electric Transformer Co., Ltd.	56

ALLEN CIRCULATING - WATER PUMPS



for

POWER STATION SERVICE in SOUTH AFRICA

The illustration shows the Pump House at Pretoria Power Station in which are installed eight circulating pump units. These comprise :—

Five 38/38-in. Allen vertical-spindle, double-suction centrifugal main circulating-water pumps, each designed to deliver 28,000 gallons per minute against a total head of 57 feet, running at a speed of 490 r.p.m., and driven by a 580-h.p. M-V motor. A sixth Allen pump unit of the same capacity is being added to complete the installation.

Also :—

Three similar Allen pumping units, with 36/36-in. branches, each designed for a capacity of 18,500 gallons per minute against a total head of 55 feet, running at a speed of 588 r.p.m., and driven by a 390-h.p. M-V motor.

Allen high-efficiency circulating-water pumps, horizontal or vertical types, are designed to meet all requirements up to the largest capacity units needed in modern power station service.

Specialists in complete Pumping Plant installations

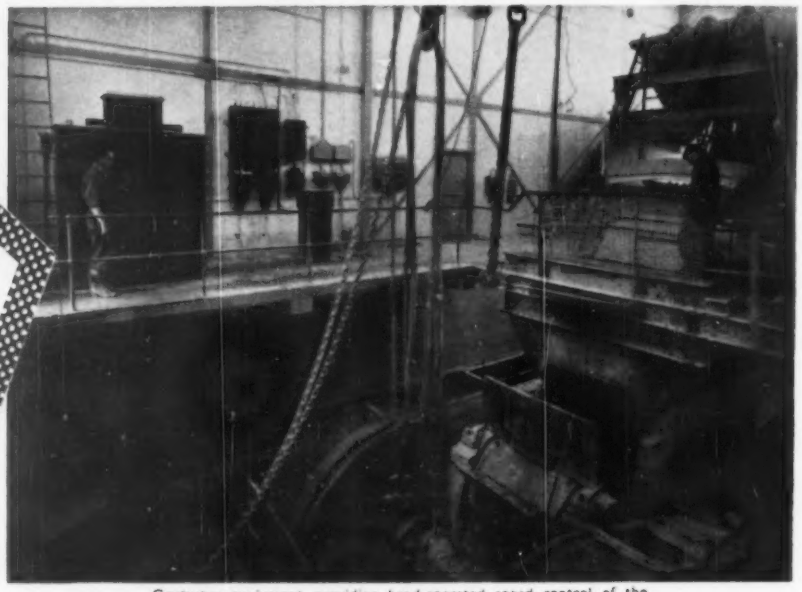
W. H. ALLEN SONS & Co LTD

BEDFORD ENGLAND

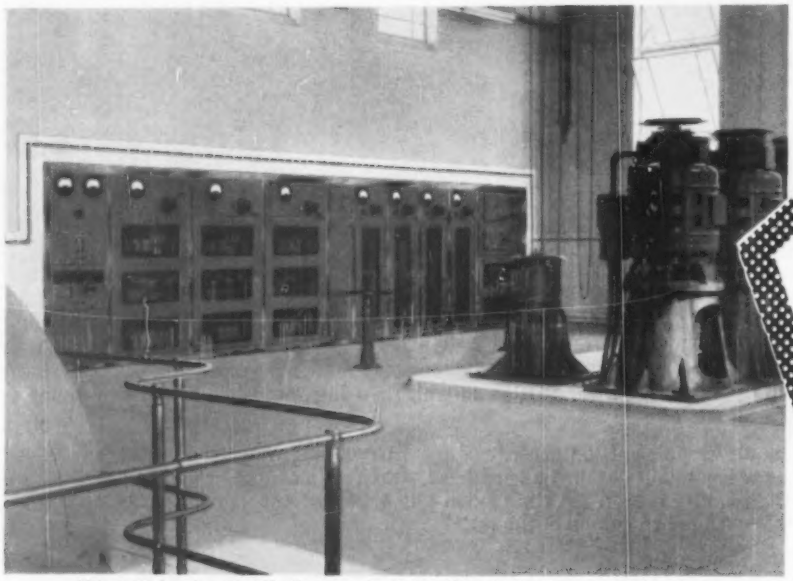
MOTOR CONTROL GEAR

for every industrial application

from the rigours of a Stone Quarry...



Contactor equipment providing hand-operated speed control of the Primary Crusher of Cornelly Quarry of The Steel Company of Wales Ltd



... to the elegance of a Pumping Station

Main control equipment at Hardham Pumping Station of North-West Sussex Joint Water Board

For every electric motor
there is an Allen West starter

ALLEN WEST

ALLEN WEST & CO LTD BRIGHTON ENGLAND · Telephone: Brighton 23291 · Telegrams: Control, Brighton
Engineers and Manufacturers of Electric Motor Control Gear and Switchgear
SUBSIDIARY COMPANIES IN CANADA, SOUTH AFRICA AND RHODESIA · AGENCIES THROUGHOUT THE WORLD

Cranes for Power Houses

The diverse resources of ARROL continue to play a vital part in maintaining Britain's power supply. Their skill is symbolised in the structural steel work of many major projects and in such powerhouse cranes as that illustrated here—100 ton capacity crane at Prince Dock Generating Station 'B', Plymouth. Similar cranes have been constructed up to a capacity of 260 tons for installations in many parts of the world and in addition a considerable number of cranes of 200 tons capacity have been constructed for the works of transformer and generating equipment manufacturers.

Cranes and Mechanical Engineering work; all types of Steel Framed Buildings; Fixed and Opening Bridges; Dock Gates; Sliding and Floating Caissons; Compressed Air Locks; Hydraulic Machinery; Pipe Lines, Surge Tanks, Sluices and other equipment for Hydro-Electric Projects.

SIR WILLIAM ARROL & CO LTD GLASGOW

Arrol

Design,

Skill

and

Service

combine to produce

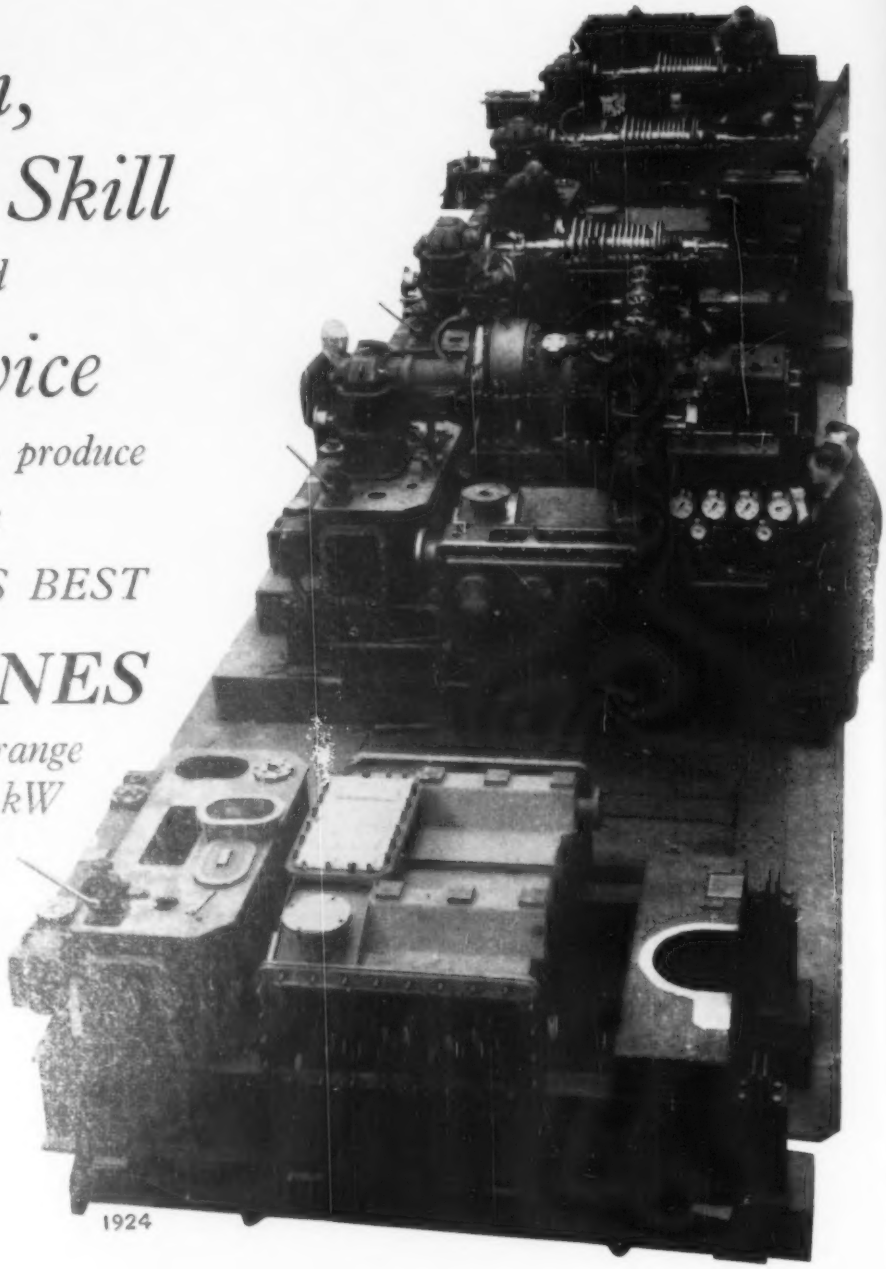
the

WORLD'S BEST

TURBINES

in the smaller range

up to 15,000 kW

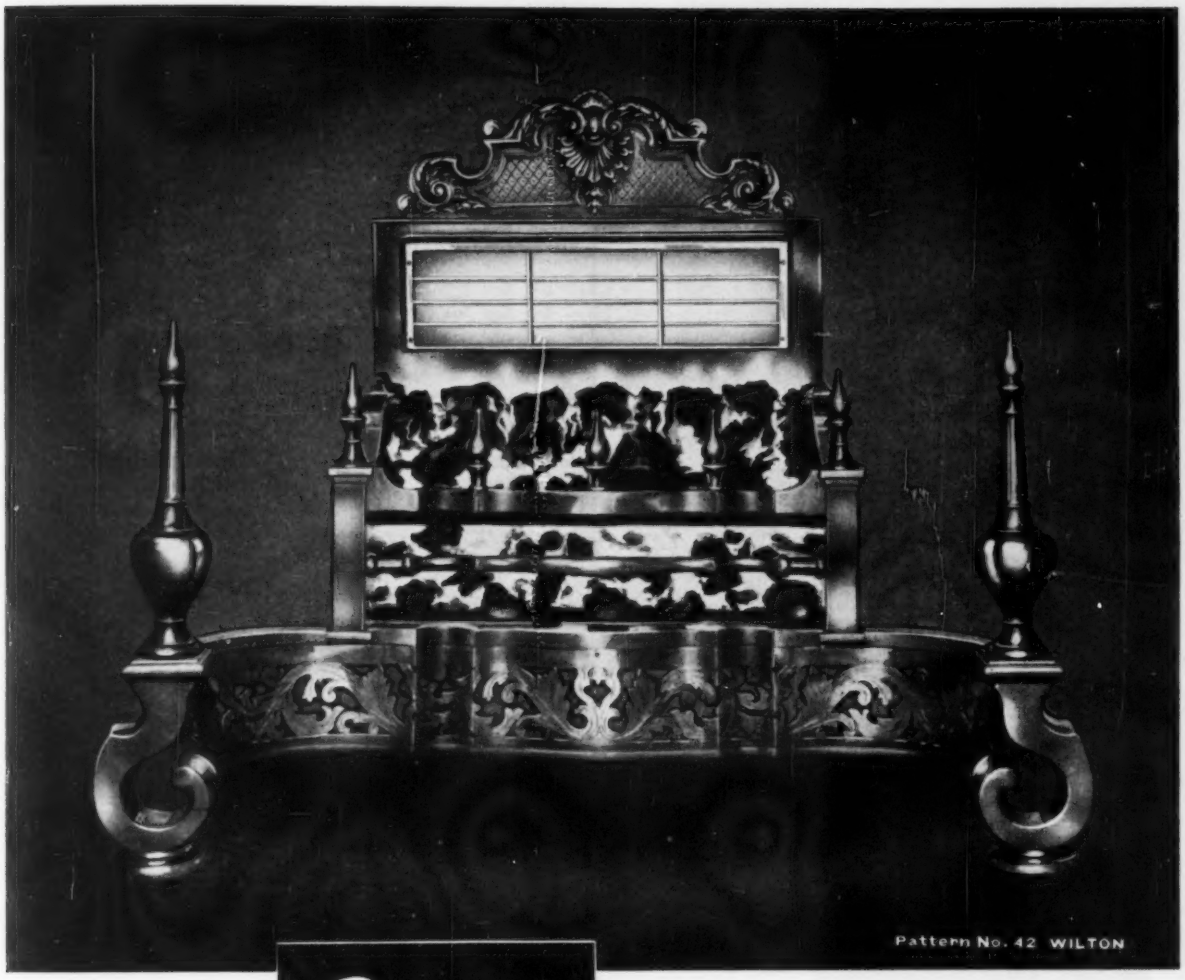


A line of 340 b.h.p. turbines in course of construction in our Turbine Erecting Shop

BELLISS & MORCOM LTD

BIRMINGHAM 16 ENGLAND

Manufacturers of :— STEAM TURBINES — STEAM ENGINES — CONDENSING PLANTS AIR & GAS COMPRESSORS—VACUUM PUMPS—DIESEL ENGINES DUAL FUEL ENGINES—'ARCA' pressure & temperature REGULATORS



From Berry's come the best

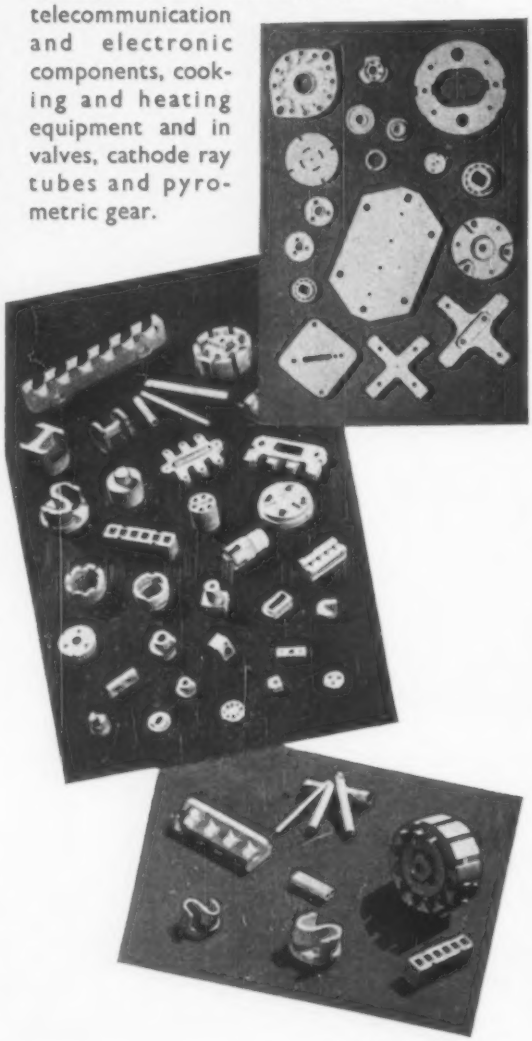
ELECTRIC FIRES	Magicoal and Berrylog—all the comfort of an open fire at the touch of a switch!
ELECTRIC LIGHT FITTINGS	period and contemporary designs in glass, metal, wood and fabric
ELECTRIC WATER HEATERS	in all standard types and sizes from 1½ to 20 gallons
ELECTRIC SWITCHGEAR	single units and complete boards for all industrial purposes

BERRY'S ELECTRIC LTD · TOUCHBUTTON HOUSE · NEWMAN STREET · LONDON W1 · MUSeum 6800

BRAY

ELECTRO-CERAMIC INSULATORS

We specialise in the mass production of small electro-ceramic insulators to close dimensional tolerances for use in radio telecommunication and electronic components, cooking and heating equipment and in valves, cathode ray tubes and pyrometric gear.



ELECTRIC HEATING ELEMENTS

These elements, of the refractory-embedded metal-sheathed type, are available in strip, ring, pad, cartridge and sheathed-wire (Tubalox) form. They are extensively used, in the medium temperature field, both for domestic and industrial purposes. Complete air-heaters and immersion heaters are also supplied.

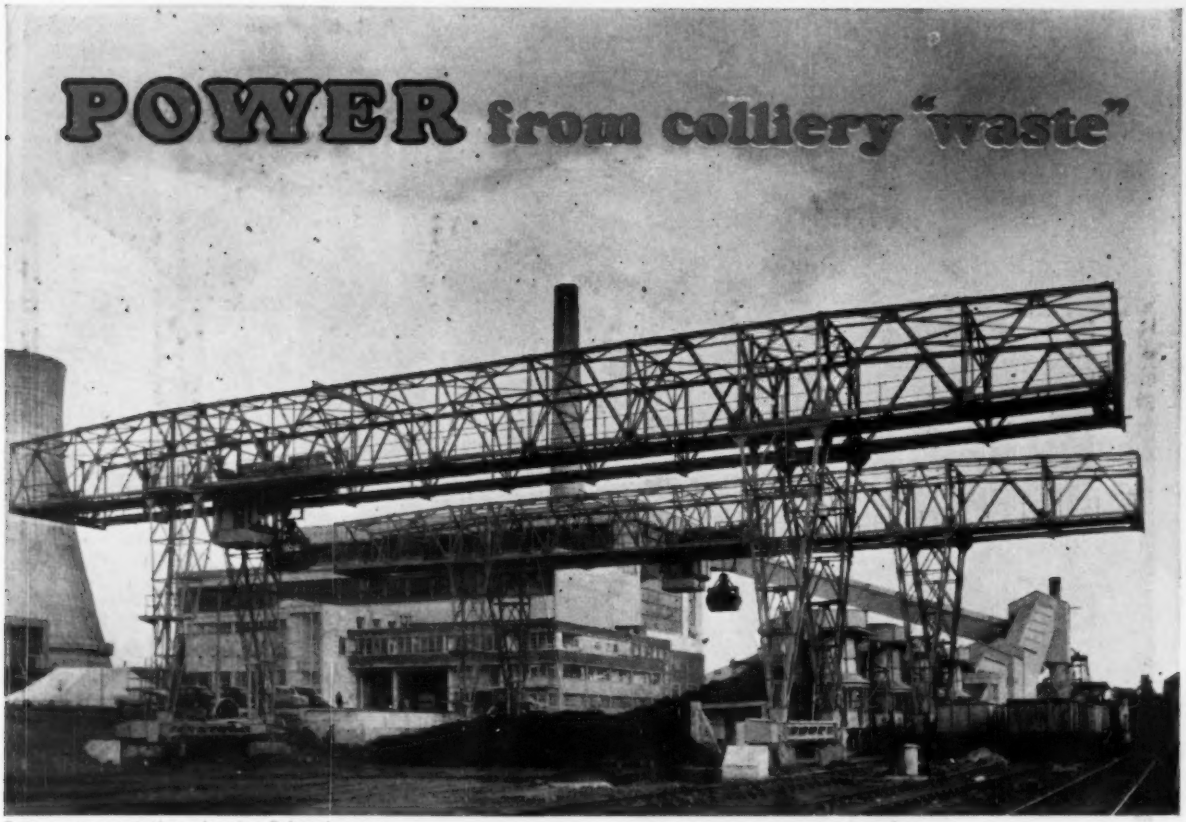
Please write for our latest Catalogues

GEO. BRAY & CO. LTD · LEICESTER PLACE · LEEDS 2

Tel. Leeds 20981 (9 lines)

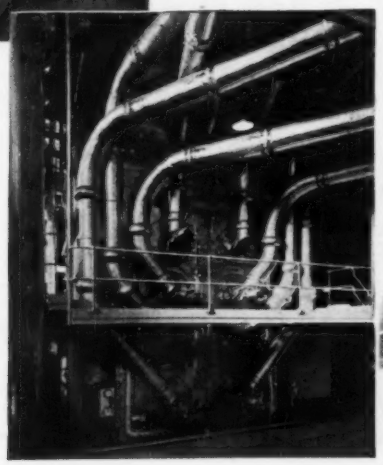
Grams "BRAY LEEDS 2"

POWER from colliery "waste"



Barony power station, showing Babcock cranes, rotary hoppers and fuel conveyor system.

Line of Babcock rotary hoppers for handling slurry to the drying and pulverizing mills feeding the boilers.



P.F. burners and fuel piping on one of the boilers.

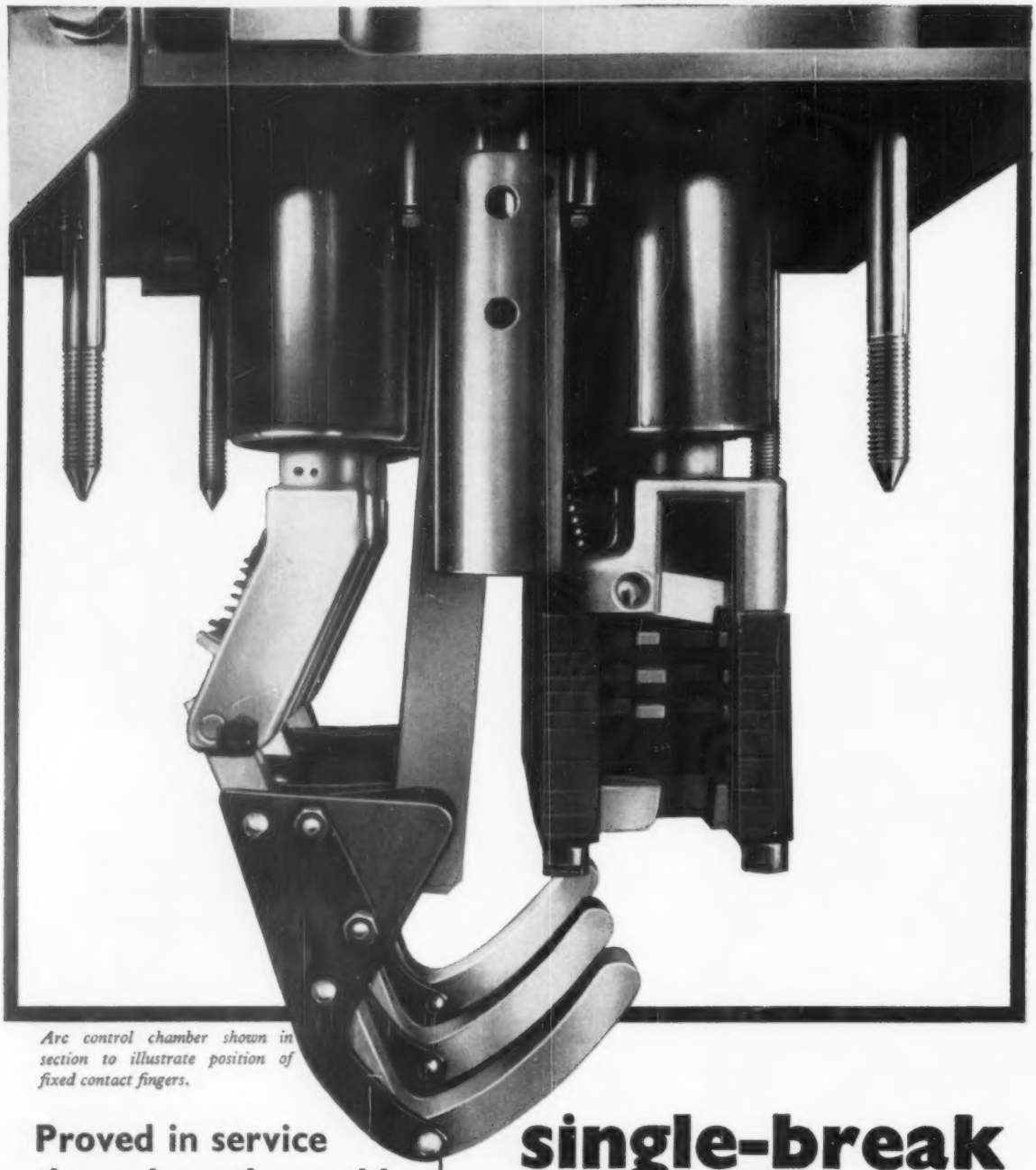
The whole of the boiler plant for the new Barony power station (South of Scotland Electricity Board), comprising four 150,000 lb./hr. pulverized-coal-fired boilers, and the whole of the coal and ash handling equipment, are of BABCOCK design and manufacture.

Outstanding feature of this installation is its ability to use as fuel, "washery-slurry"— a wet, putty-like and previously unusable by-product of the coal-washing plants.

This has been made possible through the development by Babcock & Wilcox of new, economic methods and equipment for the handling and preparation of "washery-slurry" for use as a boiler fuel — one of many BABCOCK contributions to national fuel economy.

BABCOCK
STEAM-RAISING PLANT
AND
MECHANICAL-HANDLING EQUIPMENT

BABCOCK & WILCOX LTD
BABCOCK HOUSE, 209 EUSTON RD., LONDON, N.W.1



Arc control chamber shown in section to illustrate position of fixed contact fingers.

Proved in service throughout the world

BTH single-break oil circuit-breakers—designed for metalclad switchgear—have the inherent advantages of compactness, simplicity, and ease of maintenance. The arc-control chambers and silver-plated high-pressure line contacts ensure high performance and consistent operation.

single-break oil circuit-breakers

by B T-H

up to 15 kv. **up to 2,000 amp.**

THE BRITISH THOMSON-HOUSTON COMPANY LIMITED · WILLESDEN · ENGLAND

an A.E.I. Company

A5130

BOLTON'S

BARE H.C. COPPER AND COPPER ALLOY WIRE PRODUCTS

Soft Copper Wire For power transmission overhead and underground and for telephone cables and multiple circuit transmission where physical and electrical properties and tolerances are usually to exacting specifications.

Cadmium Copper Wire (Telephone Line Wire). As supplied to the British Post Office, Crown Agents for the Colonies, etc.

Trolley Wire H.C. Copper, Cadmium Copper and Bronze.

THOMAS BOLTON & SONS LTD

THOMAS BOLTON & SONS LTD

HEAD OFFICE: Mersey Copper Works, Widnes, Lancs. Telephone: Widnes 2022. Telegrams: "Rolls, Widnes". LONDON OFFICE AND EXPORT SALES DEPT. 168 Regent St., W.1. Telephone: Regent 6427 8 9. Telegrams: "Wiredrawn, Piccy, London". WORKS: LANCASHIRE: Widnes and St. Helens. STAFFORDSHIRE: Froghall and Oakamoor, Nr. Stoke-on-Trent.

CVS-267

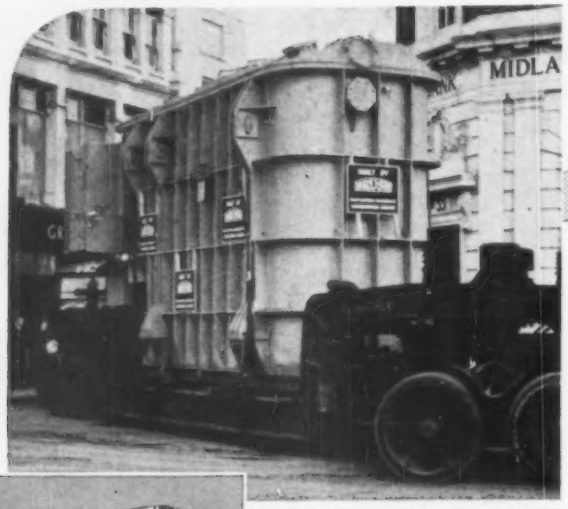
Batteries are our business

For over 60 years we have been making batteries—and nothing but batteries. Constant research and development work have kept us consistently ahead of the times in all that is new in battery construction. Today, with our batteries serving Transport, Industry and Communications in every part of the world, there are behind the names Chloride, Exide and Exide-Ironclad a wealth of experience and the full resources of the foremost battery manufacturing organisation in the Commonwealth.

CHLORIDE BATTERIES LIMITED

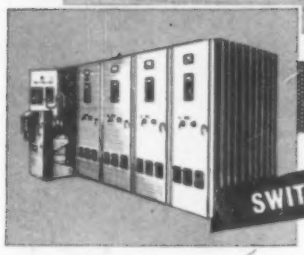
EXIDE WORKS · CLIFTON JUNCTION · SWINTON · MANCHESTER

P.17



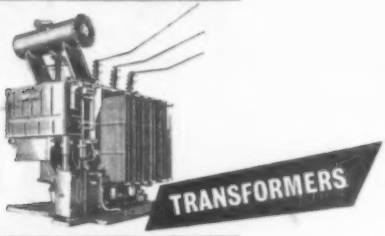
BRUSH

The logical choice



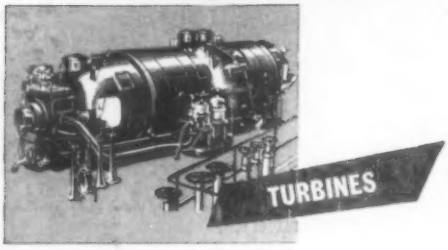
Right along the

POWER LINE



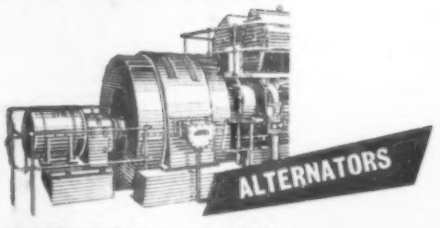
At home or abroad, wherever you see electrical power equipment serving the needs of the country—there you will find BRUSH.

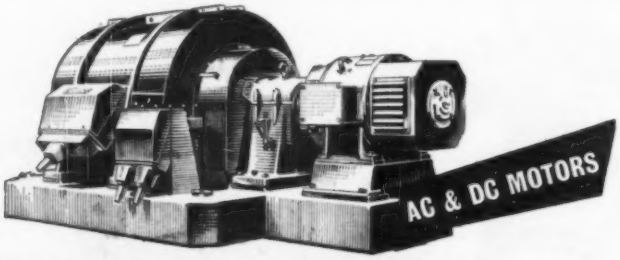
Every piece of electrical equipment made by **BRUSH**, from a small motor to a large turbine, is the trustee of an unrivalled reputation for quality throughout the world.

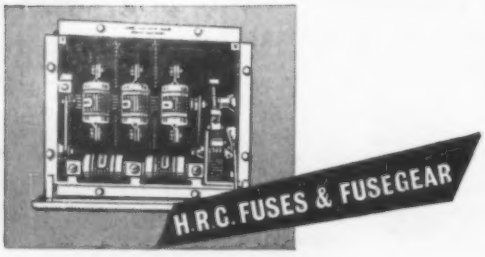


Allied to this is the perfection which governs the thinking of Brush technicians, who are always at your service to advise on power installations, without obligation.

Write for Brush Products Book, Publications No. 95052





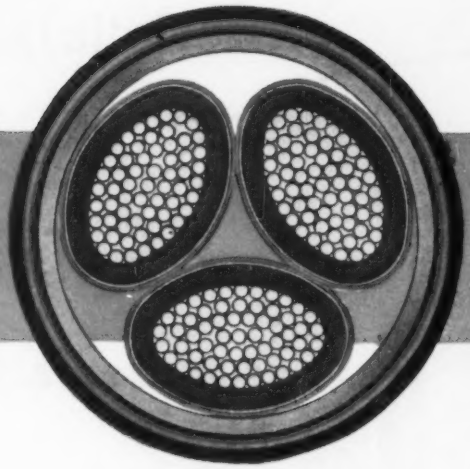


BRUSH ELECTRICAL ENGINEERING CO · LTD

Loughborough · England · (Member of the Brush Group)

● LONDON ● CARDIFF ● LEEDS ● BATH ● SHEFFIELD ● NOTTINGHAM
● BIRMINGHAM ● MANCHESTER ● NEWCASTLE ● GLASGOW ● DUBLIN

G.P.1



D S O

FOR ECONOMY

in Oil-filled Cables

Here is BICC's latest development in 33kV power transmission — the Ductless, Shaped-Conductor, Oil-filled Cable. Dispensing with fillers and built-in ducts, this new design is essentially one of economy in materials, resulting in reduced cable costs. A full range of joints and terminations has been specially designed by BICC for use with this cable.

D.S.O. Cables can be supplied with aluminium sheaths or reinforced lead sheaths and copper or aluminium conductors. Frequently the all-aluminium D.S.O. Cable (aluminium conductors and aluminium sheath) offers the most economical design.

Further information on D.S.O. Cables is contained in Publication No. 392 available on request.

SOUTH AFRICA ... *the First installation*

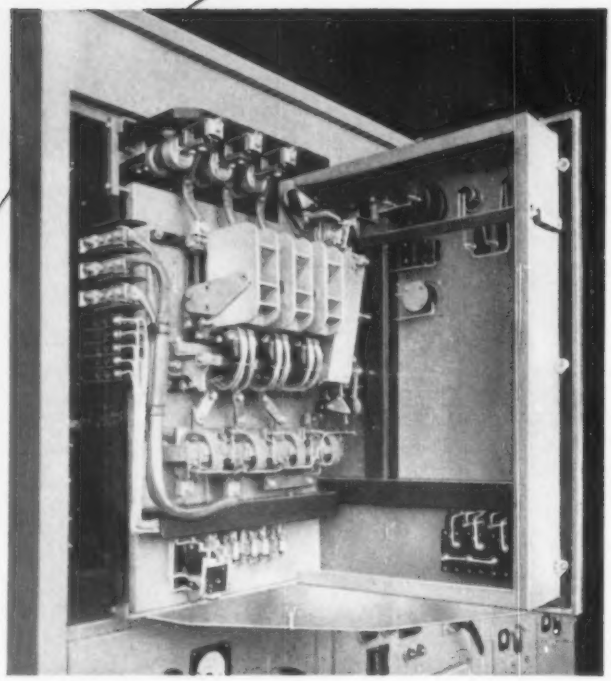
The advantages of D.S.O. Cables have already been recognised. Some 21,000 yards of 33kV *aluminium sheathed, aluminium conductor* cables are being installed at Bloemfontein, South Africa by our associate BICC (S.A.) (Pty.) Ltd. This project will link Bloemfontein power station with major distribution points at Bayswater and Dan Pienaar.

BICC

DUCTLESS SHAPED-CONDUCTOR OIL-FILLED

33kV CABLES

BRITISH INSULATED CALLENDER'S CABLES LIMITED · 21 Bloomsbury Street, London, W.C.1



UNIQUE SWING-OUT FEATURE

MAXIMUM FLEXIBILITY

MAXIMUM SAFETY AND PROTECTION

Designed to satisfy the most stringent conditions the recently introduced BROOKHIRST "CHESTER MAJOR" switchboard offers distinct advantages.

The illustration above shows how an individual starter, mounted on inside of lift-off cubicle door, swings out for inspection. If required, the complete starter unit can be instantly removed for servicing. Plug-in isolating contacts dispense with trailing cables.

Other commendable features include flexible multi-tier arrangement of starters of various types and ratings; ready interchange of units or additions on site; doors mechanically and electrically interlocked; 35 MVA short-circuit protection.

BROOKHIRST

"CHESTER MAJOR" SWITCHBOARD

BROOKHIRST SWITCHGEAR LIMITED CHESTER

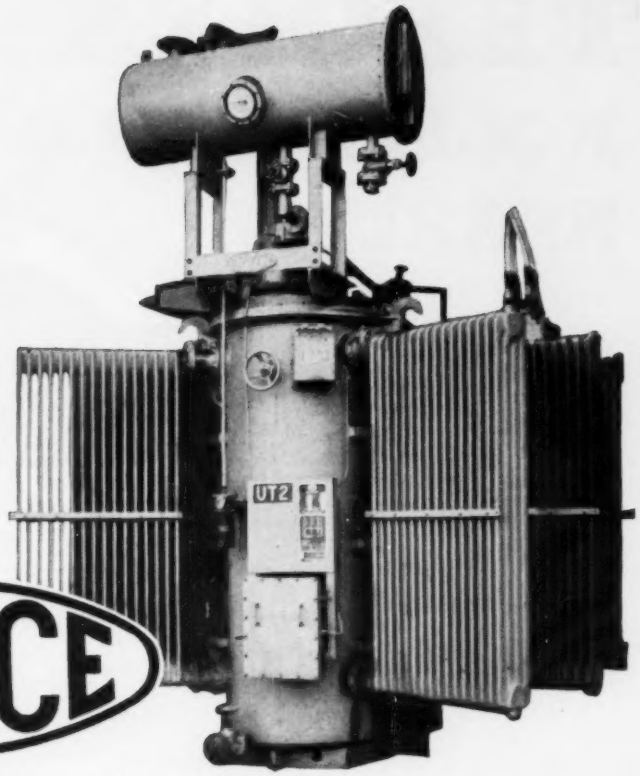
A METAL INDUSTRIES GROUP COMPANY

If you would like to examine a "CHESTER MAJOR" Switchboard your local Brookhirst Branch Office will be pleased to arrange this.

CVS-51

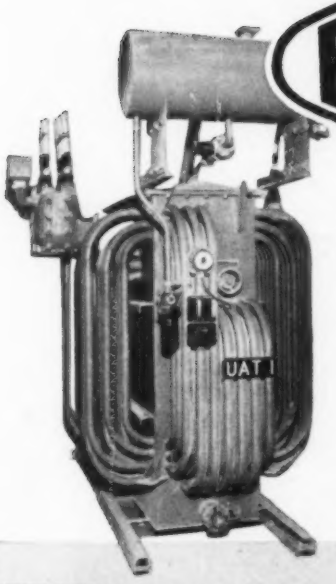
Installations at South Denes

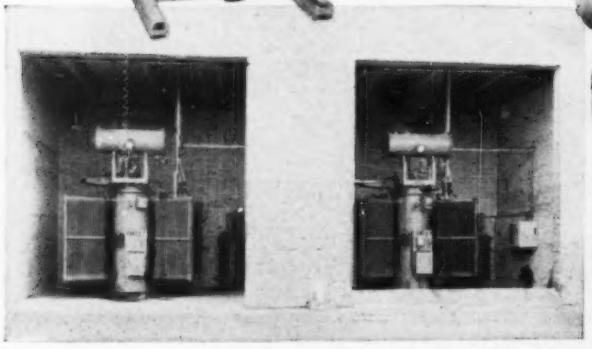
New Power Station for
C.E.G.B. EASTERN DIVISION



14 BRYCE Transformers

Ten of the fourteen Bryce Transformers for auxiliary services at the new C.E.G.B. Eastern Division Power Station are now in service.
They range from 5,000 kVA, 11,000/3,450 volts to 400 kVA, 3,300/433 volts.



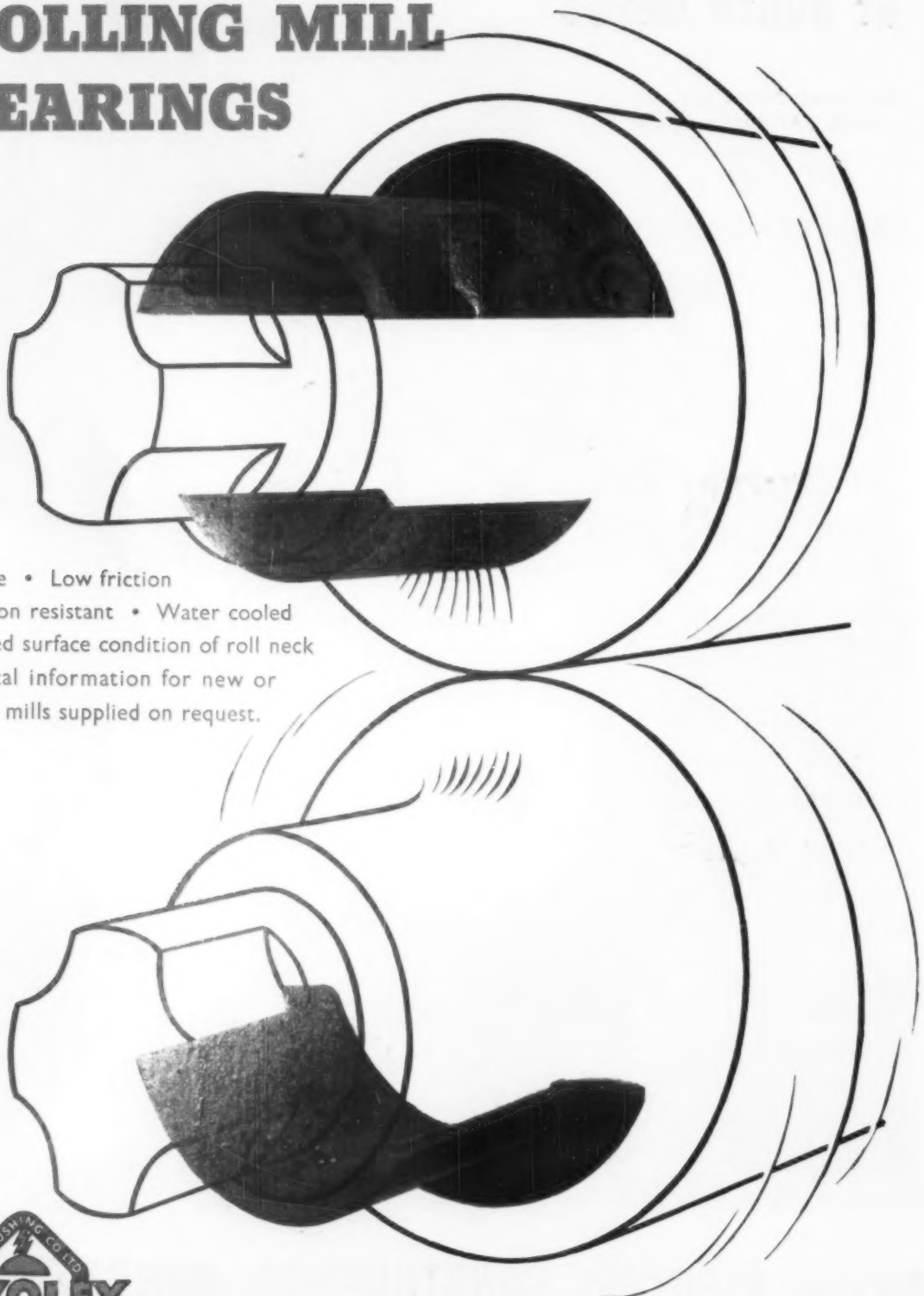


The examples illustrated are (top right and bottom left) 5,000 kVA, 11,000/3,450 volts; (upper left) 1,000 kVA, 3,300/433 volts; and (bottom right) 400 kVA, 3,300/433 volts.

BRYCE ELECTRIC CONSTRUCTION COMPANY LTD.

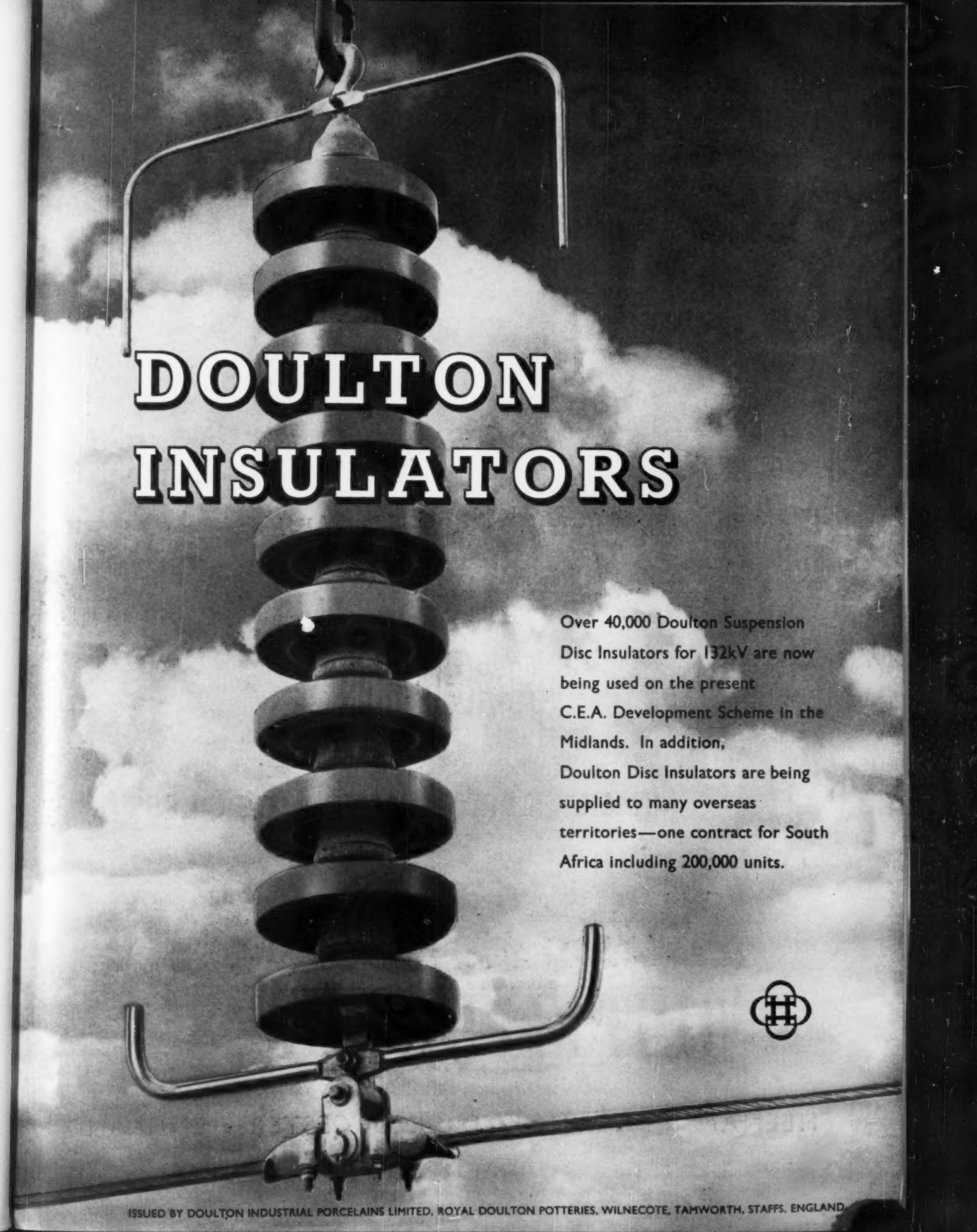
KELVIN WORKS HACKBRIDGE SURREY • TELEPHONE: WALLINGTON 2601
In Association with HACKBRIDGE CABLE CO. LTD.

TEXOLEX
ROLLING MILL BEARINGS



Long life • Low friction
Corrosion resistant • Water cooled
Improved surface condition of roll neck
Technical information for new or existing mills supplied on request.

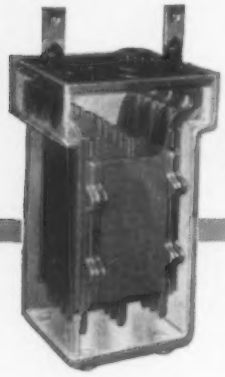
THE BUSHING COMPANY LTD. HEBBURN ON TYNE
TELEPHONE: HEBBURN 32241 • TELEGRAMS: BUSHING HEBBURN


DOULTON
INSULATORS
Over 40,000 Doulton Suspension Disc Insulators for 132kV are now being used on the present C.E.A. Development Scheme in the Midlands. In addition, Doulton Disc Insulators are being supplied to many overseas territories—one contract for South Africa including 200,000 units.
ISSUED BY DOULTON INDUSTRIAL PORCELAINS LIMITED, ROYAL DOULTON POTTERIES, WILNECOTE, TAMWORTH, STAFFS. ENGLAND.

DP stationary batteries

For whatever purpose a stationary battery is required, in any capacity from 10 to 15,000 ampere-hours, there is a D.P. type specially designed to meet the need with the utmost efficiency and economy.

A 10,200 Ampere-hour D.P. cell in a wood lead-lined box.



A sealed type 75 Ampere-hour D.P. cell as used for emergency lighting and power stations.

J 321 A

The D.P. Battery Co. Limited, Bakewell, Derbyshire. Phone : Bakewell 81

LONDON : 66 VICTORIA STREET, S.W.1. Phone : Victoria 9661/2

HEENAN

CLOSED CIRCUIT

AIR COOLERS

for ventilation of turbo-alternators
Lengthy experience in practical design
Wide variety of ducting and damper layouts
Highly efficient cooling surfaces
Heavy and robust construction
Special attention to ease of access and maintenance

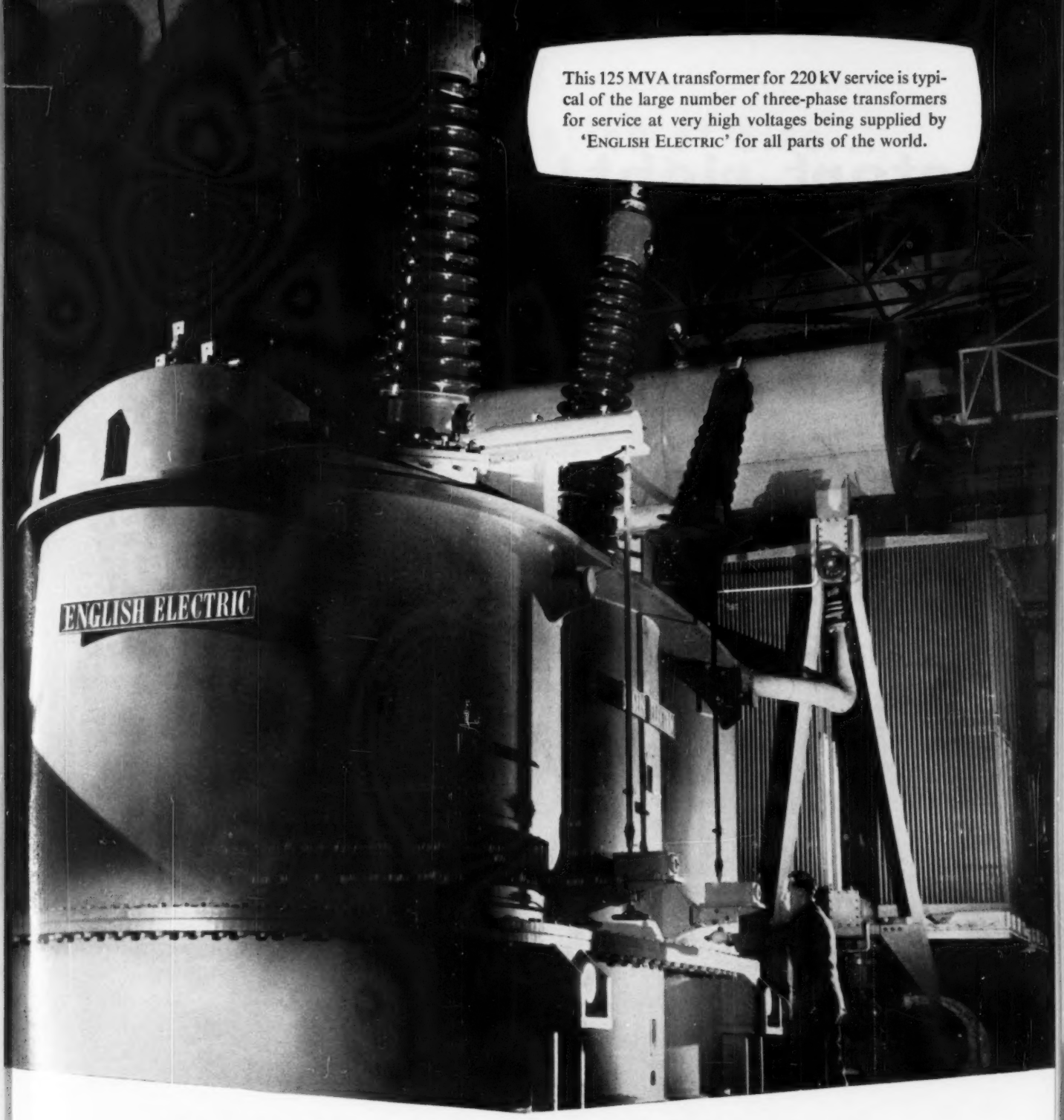
FORCED DRAUGHT

WATER COOLERS

for cooling circulating water of Diesel, Gas and Petrol Engines, Refrigerating Condensers, Air Compressors, Liquid Controllers, Process Works, etc.
Save 95% of water otherwise wasted
Robust and compact all-metal construction
Install in- or out-of-doors

H&F

HEENAN & FROUDE LTD : WORCESTER : ENGLAND



This 125 MVA transformer for 220 kV service is typical of the large number of three-phase transformers for service at very high voltages being supplied by 'ENGLISH ELECTRIC' for all parts of the world.

'ENGLISH ELECTRIC'

Power generation · Power transmission · Power control · Power distribution
Power transformation · Power conversion · Power utilisation · Power measurement

Power is our Business

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2.

Partners in Progress with NAPIER, MARCONI'S, VULCAN FOUNDRY and ROBERT STEPHENSON & HAWTHORNS
in The ENGLISH ELECTRIC Group

P.65

start right!..

with this Dubilier Motor Starting Capacitor.
It is the most reliable A.C. capacitor
available for this purpose.
The capacitor element is hermetically sealed in an
aluminium inner container mounted in an outer case
of drawn steel with a strong mounting bracket
designed to withstand a good deal of rough treatment.
Dubilier Motor Starting Capacitors are specially
styled to match the motor housing.
Available in three ranges of r.m.s. voltages,
150V: from 45–65 μF to 280–340 μF; 275V: from 15–20 μF to
120–150 μF; and 350V: from 20–25 μF to 100–125 μF.
Reliable operation at maximum voltages up to 60°C.

DUBILIER

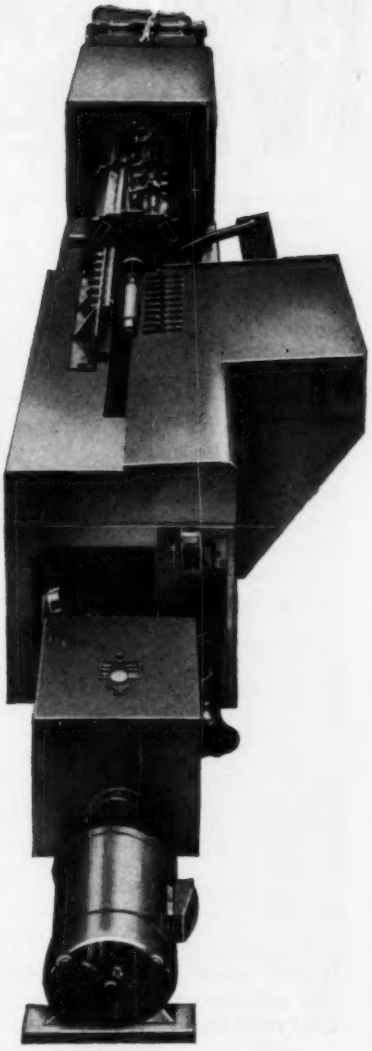
DUBILIER CONDENSER CO. (1925) LTD., DUCON WORKS, VICTORIA ROAD, NORTH ACTON, LONDON, W.3.
Telephone: ACOrn 2241
Telegrams: Hivoltcon Wesphone London.
DN184

For Hot Working
it's a Question of Size...

Choice of 50 cycle or H.F. induction heating depends to a great extent on the size of the billet.

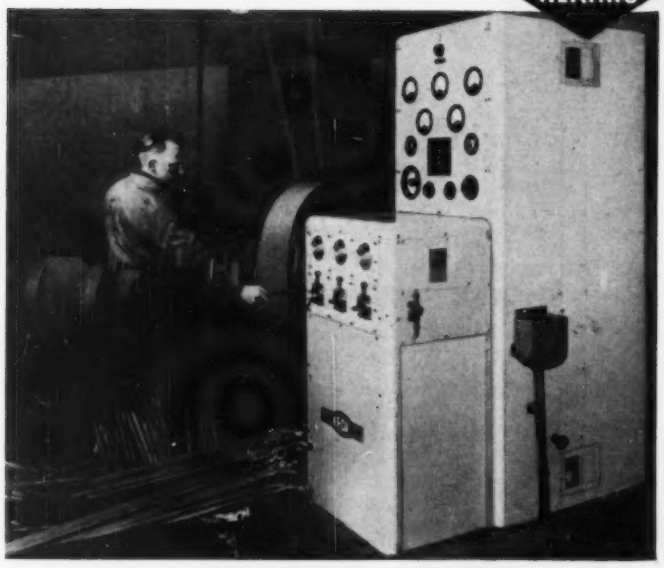
If your problem is economical heating of steel or non-ferrous metals, our lengthy experience is at your disposal.

EFCO-TOCCO Induction heating plant



FOR SMALL BILLETS

H F HEATING



50 CYCLE HEATING

FOR LARGER BILLETS

for Induction Heating – EFCO have the answer

Rainbow 1448

EFCO **ELECTRIC FURNACE COMPANY LIMITED**

NETHERBY · QUEENS ROAD · WEYBRIDGE · SURREY · Weybridge 3891

Associated with Efco Ltd., Electro-Chemical Engineering Co. Ltd., Electric Resistance Furnace Co. Ltd.

"You remember that problem which was baffling us last week?"
"Yes."
"Well, there's a technique described in this month's ELECTRICAL ENERGY which will, I think, find the answer for us. Have a shot at it. If it works, our troubles are over."

Wherever problems in Electrical Engineering are the topic, this is the sort of conversation which will be heard.

Do you see ELECTRICAL ENERGY every month? A year's subscription costs no more than the average text book, but the information provided month by month is always up to date and comes in easily digested portions.

Subjects covered include the following:

Analysers · Cables · Capacitors
Computation & Mathematical Techniques
Energy Supplies · Fuses
Generation and Power Supply
Insulation and Dielectrics
Machine Control · Magnetic Amplifiers
Magnetic Materials and Properties
Measurement and Test Equipment
Mining Equipment · Motors · Nuclear Power
Protective Equipment
Rectifiers and Convertors
Servomechanisms · Traction
Transformers · Transmission

If your work is connected with any of them you will find a subscription to ELECTRICAL ENERGY will be a valuable investment.

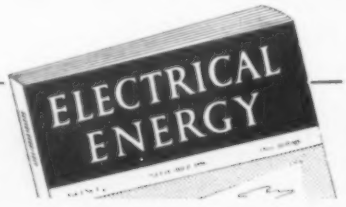
Annual Subscription **£1 16 0** Single copies **3s.**

Order through your newsagent or direct from:

ELECTRICAL ENERGY
28 ESSEX STREET, STRAND, LONDON, W.C.2

Published monthly by:
MORGAN BROTHERS (Publishers) LIMITED

Proprietors of
"The Engineer"
and
"Electronic Engineering"



The Electrical Industries Benevolent Association

★

THE OBJECTS OF THE ASSOCIATION are to grant Pensions and to dispense Temporary Relief to deserving and necessitous Persons who are or have been engaged in the Electrical Industry in the United Kingdom as Employers, Managers, Teachers, or on the Engineering, Designing, Drawing, Sales or Office Staff, or in any other similar capacities, or to their Dependants.

SUPPORTED BY (*a*) Associates (annual subscription of 5/-); (*b*) Members (annual subscription of 20/-); (*c*) Honorary Subscribers, *i.e.* contributors not qualified for assistance; (*d*) Donors, *i.e.* contributors not qualified for assistance; (*e*) Bequests; (*f*) Revenue from Investments.

Full particulars sent on application to
THE SECRETARY, 10 BUCKINGHAM PALACE GARDENS, LONDON, S.W.1

GENERATION, TRANSMISSION AND UTILIZATION OF ELECTRICAL POWER

By A. T. STARR, M.A., PH.D., M.I.E.E. New and revised 4th Edition. This book has been specially written to meet the requirements of the 'Electrical Power' syllabus of the Engineering Degree. It covers a very wide field and yet deals with each branch of the subject in considerable detail. In this new edition an additional Appendix on nuclear energy has been added and an outline of the Calder Hall Station is given. Pitman's 'Engineering Degree Series.' **27/6** net.

"Its technical soundness and clear exposition of principles should ensure its success with teachers and students."—*ELECTRICIAN* (from a review of a previous edition).

PITMAN *Parker Street, Kingsway, London, WC2*

for the technologists of tomorrow

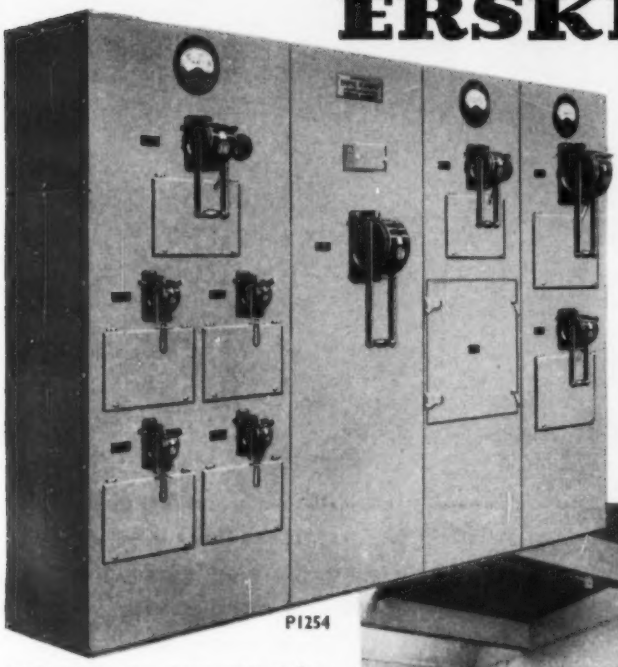
'ERSKINE HEAP'

Switchgear and Motor Control gear

is installed in

- *UNIVERSITIES*
- *COLLEGES &*
- *SCHOOLS*

throughout the country

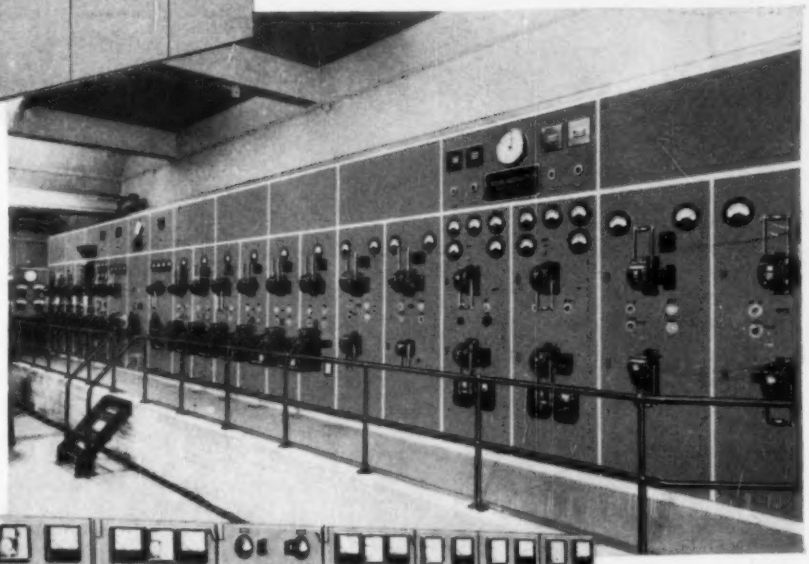


P1254 One of several Switchboards supplied for big new Lancashire School. This switchboard comprises back-of-board type switches, fuses and contactors with front-of-board operation.

P1254

P1256 Illustration shows main switchboard controlling power and lighting at Manchester College of Science and Technology. Switches are of 25 MVA rupturing capacity, tested to BS.116 at 400 volts. Duplicate bus bars are provided with front-of-board operated changeover switches for changing over between the College's own Turbo Alternator set and Electricity Board.

P1263 Switchboard illustrated below is one of several supplied recently to control the power and lighting of the Chemistry & Engineering Building, Queen's University, Belfast, the two incoming units and bus bar coupler being 1600 amp. capacity.



P1256

P1263

VISIT US AT STAND O.4

EARLS COURT ELECTRICAL ENGINEERS A.S.E.E. EXHIBITION

MARCH 25th to 29th 1958

ERSKINE, HEAP & Co LTD

SWITCHGEAR SPECIALISTS

Head Office & Works BROUGHTON, MANCHESTER (7)

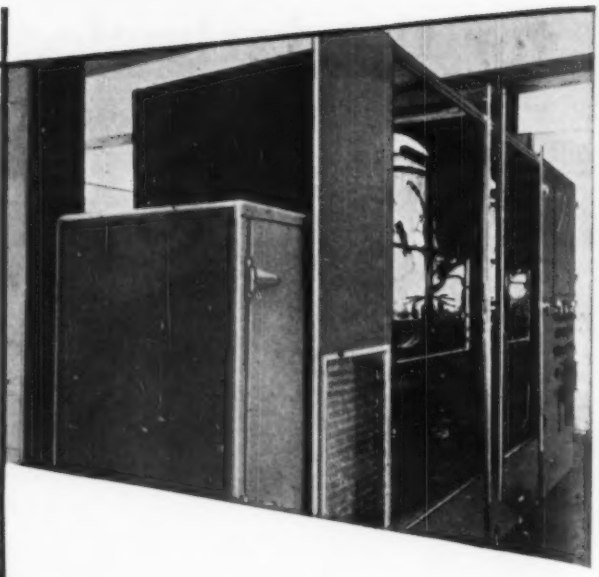
London Office GRAND BUILDINGS, TRAFALGAR SQ., W.C.2

BRANCH OFFICES AND AGENCIES IN ALL PARTS OF THE WORLD

723

EVERYWHERE AND ANYWHERE

Hewittic Rectifiers give reliable service . . .



The robustness, lightness, and manœuvrability of Hewittic Rectifiers make them ideal for installation in awkward situations, and their outstanding operational characteristics, proved over a period of 50 years, ensure utmost reliability and long service.

For every type of A.C.-D.C. application and from the smallest sizes up to any capacity.

★ ***The photographs show a 300 kW. Hewittic Rectifier substation in mining traction service in Mexico.***

Hewittic Rectifiers

OVER 1½ MILLION KW. IN WORLD WIDE SERVICE

Send for details

HACKBRIDGE AND HEWITTIC ELECTRIC CO., LIMITED
WALTON-ON-THAMES - SURREY - ENGLAND
Telephone: Walton-on-Thames 760 (8 lines) *Telegrams & Cables: "Electric, Walton-on-Thames"*

OVERSEAS REPRESENTATIVES

ARGENTINA: H. A. Roberts & Cia., S.R.L., Buenos Aires. AUSTRALIA: Hackbridge and Hewittic Electric Co. Ltd., 171 Fitzroy Street, St. Kilda, Victoria; N.S.W.: Queensland: W. Australia: Elder, Smith & Co. Ltd.; South Australia: Parsons & Robertson Ltd.; Tasmania: H. M. Bamford & Sons (Pty.) Ltd., Hobart. BELGIUM & LUXEMBOURG: M. Dorfman, 5 Avenue des Phalenes, Brussels. BRAZIL: Oscar G. Mors, Sao Paulo. BURMA: Neonlite Manufacturing & Trading Co. Ltd., Rangoon. CANADA: Hackbridge and Hewittic Electric Co. of Canada Ltd., Montreal; The Northern Electric Co. Ltd., Montreal, etc. CEYLON: Envee Ess Ltd., Colombo. CHILE: Sociedad Importadora del Pacifico Ltda., Santiago. EAST AFRICA: Gerald Hoe (Lighting) Ltd., Nairobi. EGYPT: Giacomo Cohenca Fils, S.A.E., Cairo. FINLAND: Sähkö-ja Koneliike O. Y. Hermes, Helsinki. GHANA, NIGERIA & SIERRA LEONE: Glyndova Ltd. NETHERLANDS: J. Kater E.I., Ouderkerk a.d. Amstel, Amsteldijk Noord 103e. INDIA: Steam & Mining Equipment (India) Private Ltd., Calcutta; Easun Engineering Co. Ltd., Madras, I. IRAQ: J. P. Bahoshy Bros., Baghdad. MALAYA, SINGAPORE & BORNEO: Harper, Gilfillan & Co. Ltd., Kuala Lumpur. NEW ZEALAND: Richardson, McCabe & Co. Ltd., Wellington, etc. SOUTH AFRICA: Arthur Trevor Williams (Pty.) Ltd., Johannesburg, etc. CENTRAL AFRICAN FEDERATION: Arthur Trevor Williams (Pty.) Ltd., Salisbury. THAILAND: Vichien Phanich Co. Ltd., Bangkok. TRINIDAD & TOBAGO: Thomas Peake & Co., Port of Spain. TURKEY: Dr. H. Salim Öker, Ankara. U.S.A.: Hackbridge and Hewittic Electric Co. Ltd., P.O. Box 234, Pittsburgh 30, Pennsylvania.

F
FERRANTI

330,000 volts

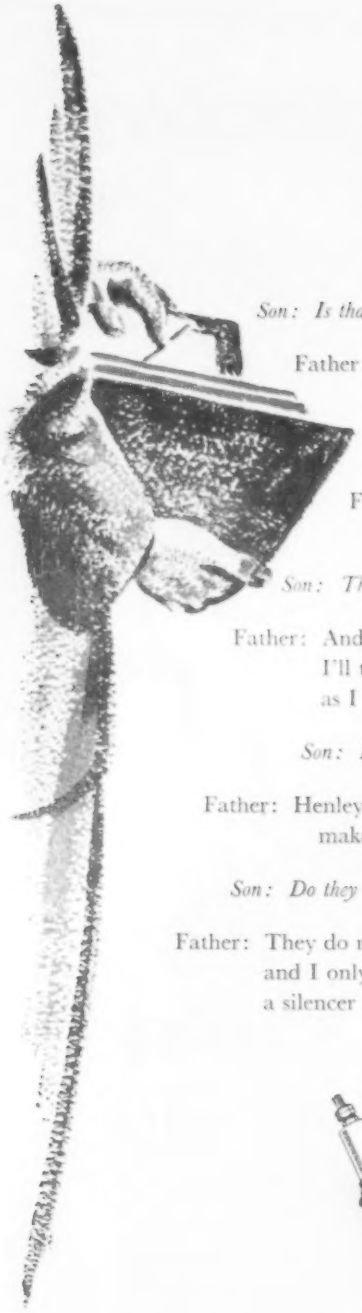
transformers for Kariba

The contract awarded to Ferranti Ltd. by the Federal Power Board for the great Kariba Hydro-Electric Scheme on the Zambesi River covers two 120,000 kVA 330/234 kV 3-phase auto transformers with separate boosters; eight 60,000 kVA 330/88 kV 3-phase double-wound transformers; and two 60,000 kVA 330/33 kV 3-phase double-wound transformers. All the transformers will be provided with on-load tap changing gear. The placing of this large and important overseas transformer contract emphasises the world-wide confidence in Ferranti Ltd. as builders of fine transformers.

FERRANTI LTD · HOLLINWOOD · LANCS
London Office: KERN HOUSE 36 KINGSWAY W.C.2

FERRANTI

FT 208/2



Son: Is that a Roman Candle with three tops, Daddy?

Father: No, son — it's called an indoor terminal box.

Son: What's it for, Daddy?

Father: Well, er . . . I'll tell you when you're twelve.

Son: That's what Mummy's always saying.

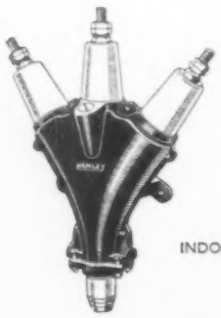
Father: And if you'll move over a bit, I'll telephone Henley's as I want some quickly.

Son: Henley's?

Father: Henley's are a large firm — they make these things.

Son: Do they make Roman Candles, too?

Father: They do not. They make electrical things, and I only wish their range included a silencer for small boys!



INDOOR TERMINAL BOX (Vertical Type) 11,000 V. *Send for Catalogue 32/3*

HENLEY **DISTRIBUTION EQUIPMENT**

W. T. HENLEY'S TELEGRAPH WORKS CO. LTD. 51/53 HATTON GARDEN . LONDON . E.C.1 . *Tel: CHAncery 6822*

Eliminate Risks — Specify . . .

Heatrae Flameproof Equipment

Every possible risk of ignition of inflammable and explosive liquids and gases has been foreseen and provided for in this range of Heatrae Flameproof Equipment.

Illustrated are :

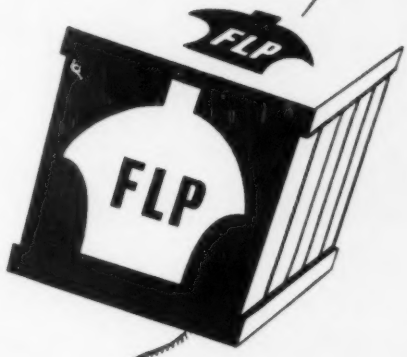
a. *A thermostat.*

b. *A removable core type immersion heater.*

c. *A five-bank gilled tube heater.*

We also make Thermal Storage Water Heaters, etc., in Flameproof Construction.

Please write for full details of our comprehensive range.

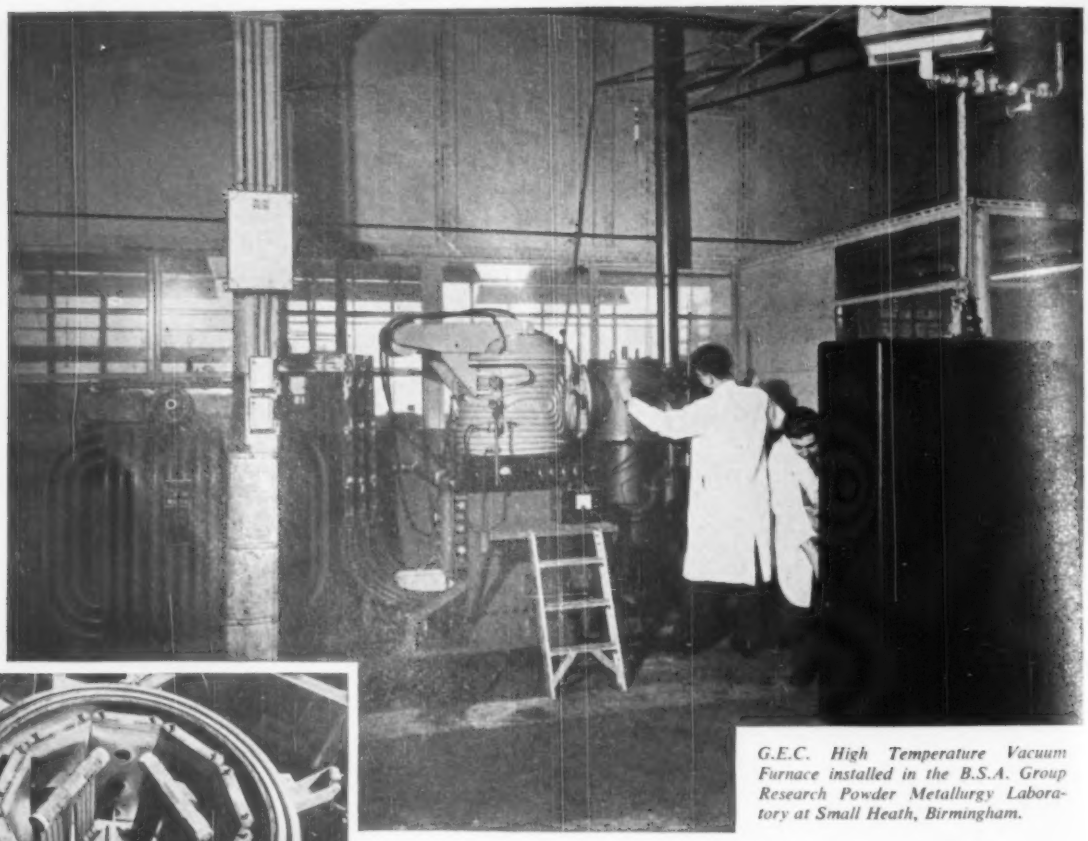


Heatrae

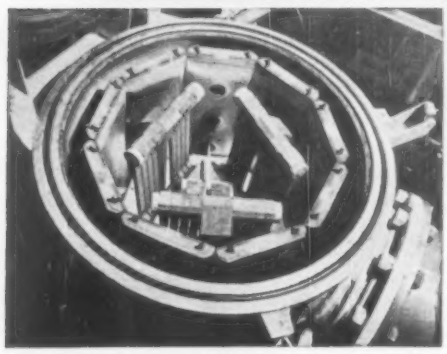
HEATRAE LIMITED · NORWICH

Manufacturers of: Electric Water Heaters, Oil Heaters, Immersion Heaters, Urns, Towel Rails, Airing Cupboard Heaters, Electric Fires, Flameproof Heating Apparatus, Breakfast Cookers, Food Trolleys, Warming Plates, Air Heaters, etc.

B.S.A. use a G.E.C. High Temperature Vacuum Furnace...



G.E.C. High Temperature Vacuum Furnace installed in the B.S.A. Group Research Powder Metallurgy Laboratory at Small Heath, Birmingham.



The furnace element assembly and side radiation screens.

for sintering materials for use at high temperatures

G.E.C. vacuum furnaces meet the need for high temperatures for such applications as sintering and degassing, brazing with nickel chromium alloys, heat treating titanium, tantalum and zirconium.

They provide an operating vacuum between 10^{-4} and 10^{-5} mm. mercury. Temperatures up to 2000°C. have been achieved.

Write for further details.

for efficient process heating use

G.E.C.

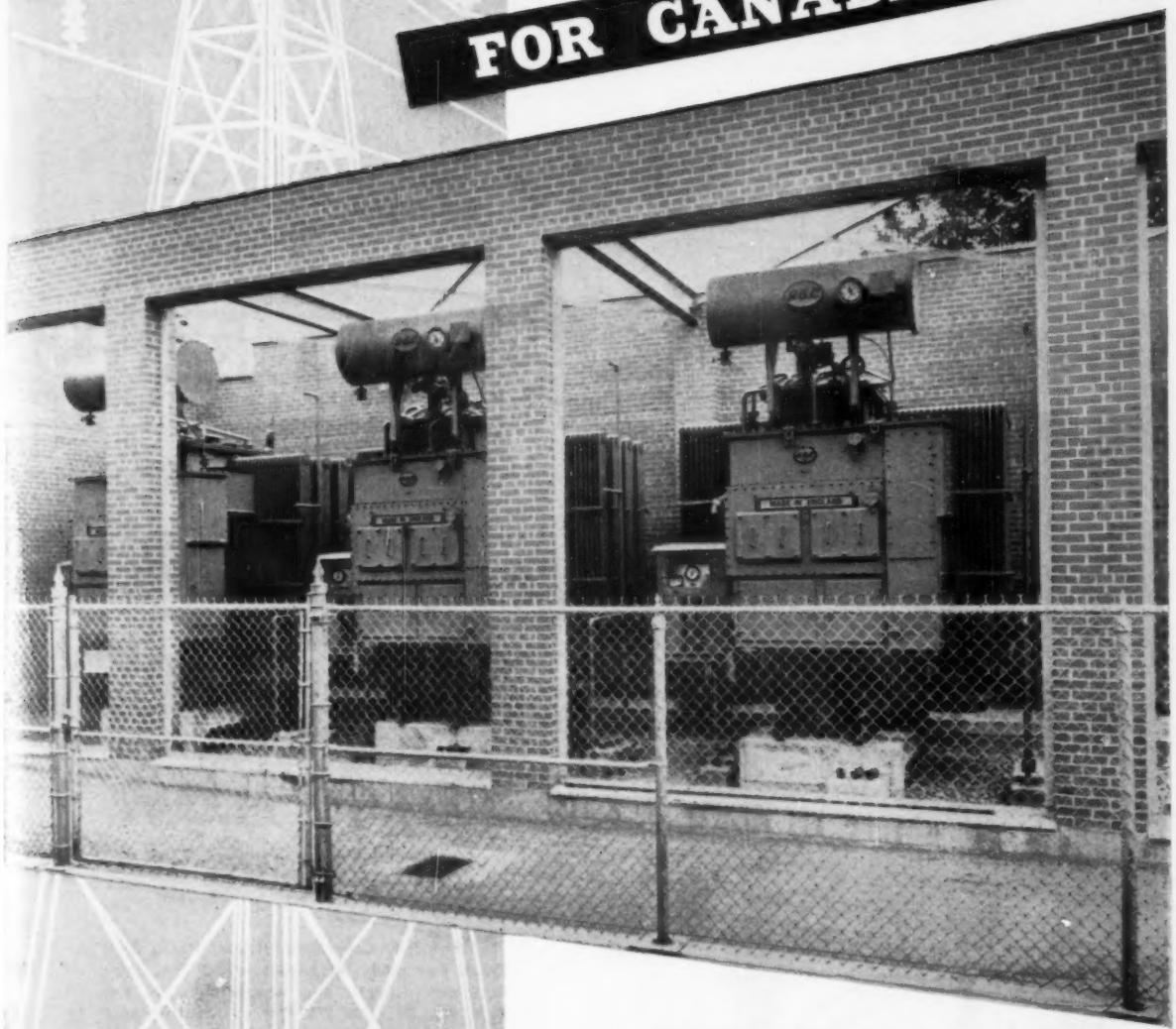
FURNACES • HIGH FREQUENCY • INFRA-RED

69

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2

G.E.C.

TRANSFORMERS FOR CANADA



5,000 kVA G.E.C. Transformers at Hammersmith Sub-station, Toronto.

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2

Feed water evaporators

SINGLE, DOUBLE & TRIPLE EFFECT

WITH VAPOUR RECOMPRESSION FOR HIGHEST EFFICIENCY

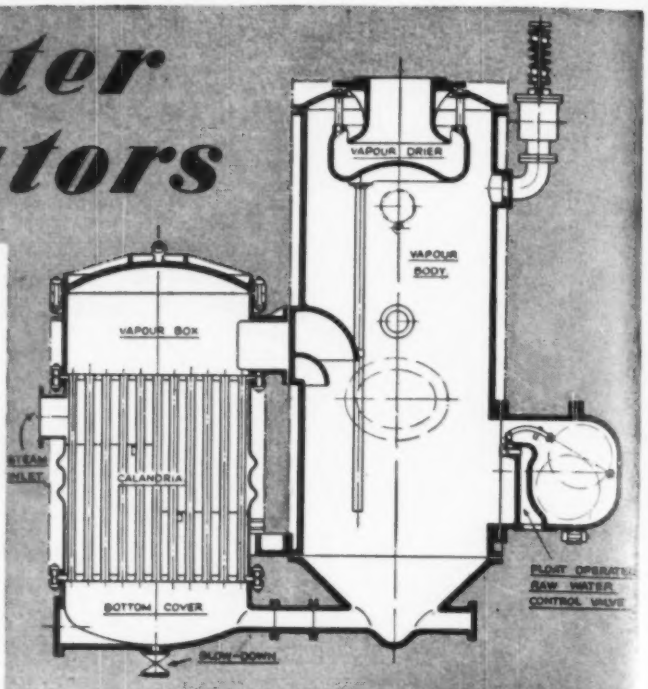
Low Vapour Velocity—
High Condensate Purity

Ample Surface—
Infrequent Cleaning

Straight Tubes—
Easy Access

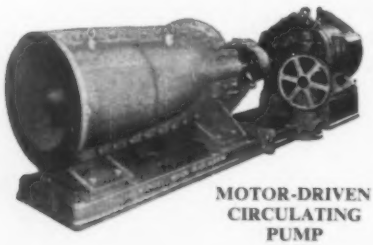
The drawing shows the sectional arrangement of a single effect Evaporator.

H.104 B

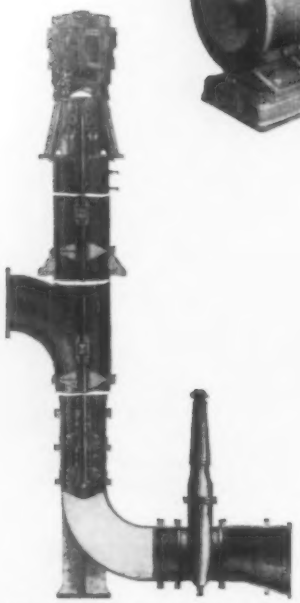


HICK HARGREAVES
AND COMPANY LTD BOLTON

'Mirrlees'



MOTOR-DRIVEN CIRCULATING PUMP



AXIAL FLOW PUMP FOR CONDENSER CIRCULATING DUTY

VERTICAL SUBMERGED TYPE

AXIAL FLOW PUMPS

For Sewage, Condenser Circulation, Dry Dock Pumping, Irrigation, etc. The illustrations indicate the adaptability of the AXIAL FLOW PUMP to varying site conditions

The MIRRLEES WATSON COMPANY LIMITED

HEAD OFFICE & WORKS: SCOTLAND ST., GLASGOW, C.5
LONDON OFFICE: 38 GROSVENOR GARDENS, S.W.1

The Jackson-Ego SPEEDRING PLATE

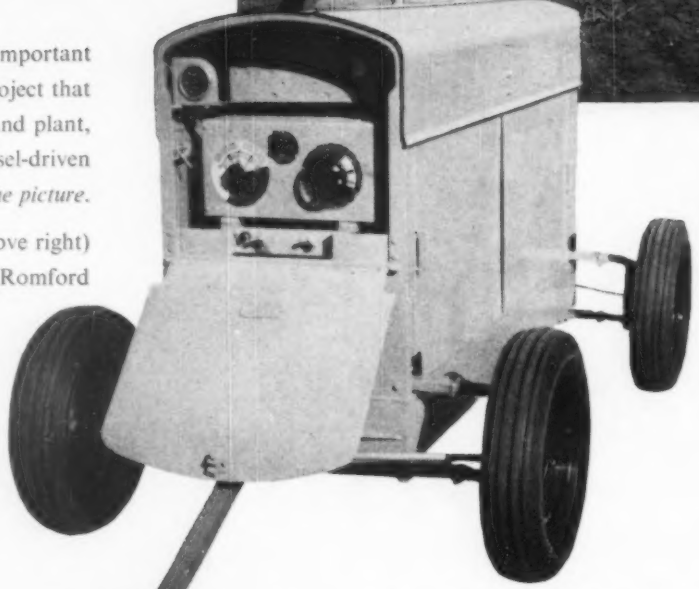
Whenever you hear of a new advance in electric cooking, the odds are that Jackson's introduced it !

For satisfaction cook with **Jackson**

THE JACKSON ELECTRIC STOVE CO. LTD., LUTON AND LONDON Branches: Belfast, Birmingham, Cardiff, Glasgow, Leeds, Liverpool, Newcastle-on-Tyne

FIRST IN THE FIELD—AND STILL IN THE LEAD

Always in the picture



Wherever in the world a really important construction project is in progress, a project that demands the very best material and plant, the Lincoln SAE 300 Diesel-driven Welding Unit is *always in the picture*.

The two pictures here show (above right) the unit in action on the Shell Haven to Romford 24" welded pipeline. The unit on this project, in addition to supplying the welding current, powered the cleaning and buffing machines. The picture below shows the unit in use on the Sandy Potton to Bedford 8" pipeline.

The Lincoln SAE 300 Diesel-driven Welder (NEMA rating 300 amp at 40 volts) is powered by the Perkins L4 Diesel Engine.

It is a versatile and compact unit, with a welding duty current range of 60-400 amp with a maximum output of 16 kw. (at 400 amp). No external reactance or Stabilizer is required.

The dual continuous control supplies uniform current for metallic arc welding, using bare or heavily coated electrodes—it can also be used for carbon-arc welding.

Combination of the independently adjustable current and open circuit voltage controls permits the operator to select any type of arc and arc intensity.

The control panel and all working parts are contained in a pressed steel weatherproof cabinet which affords easy access.

A further feature of the Lincoln SAE 300 Diesel-driven Welder is the sturdy chassis and running gear, which are unsurpassed for heavy duty field work.

LINCOLN Electric Co Ltd
Largest manufacturers of D.C. Welders in the United Kingdom

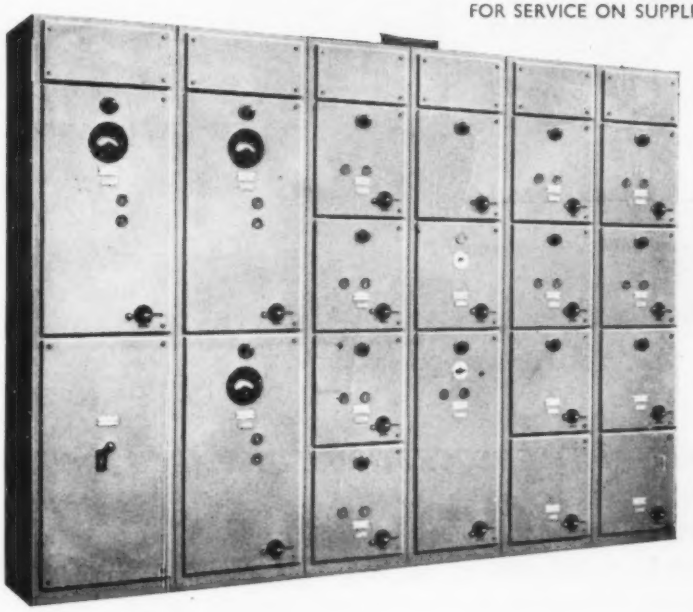
BLACK FAN ROAD · WELWYN GARDEN CITY · HERTS · WELWYN GARDEN 920 (5 lines) 4581 (5 lines)
SM10E

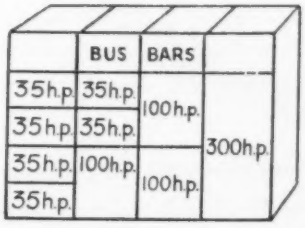
UNICUBE

REGD.

GROUP CONTROL MOTOR STARTERS

FOR SERVICE ON SUPPLIES UP TO 660 VOLTS





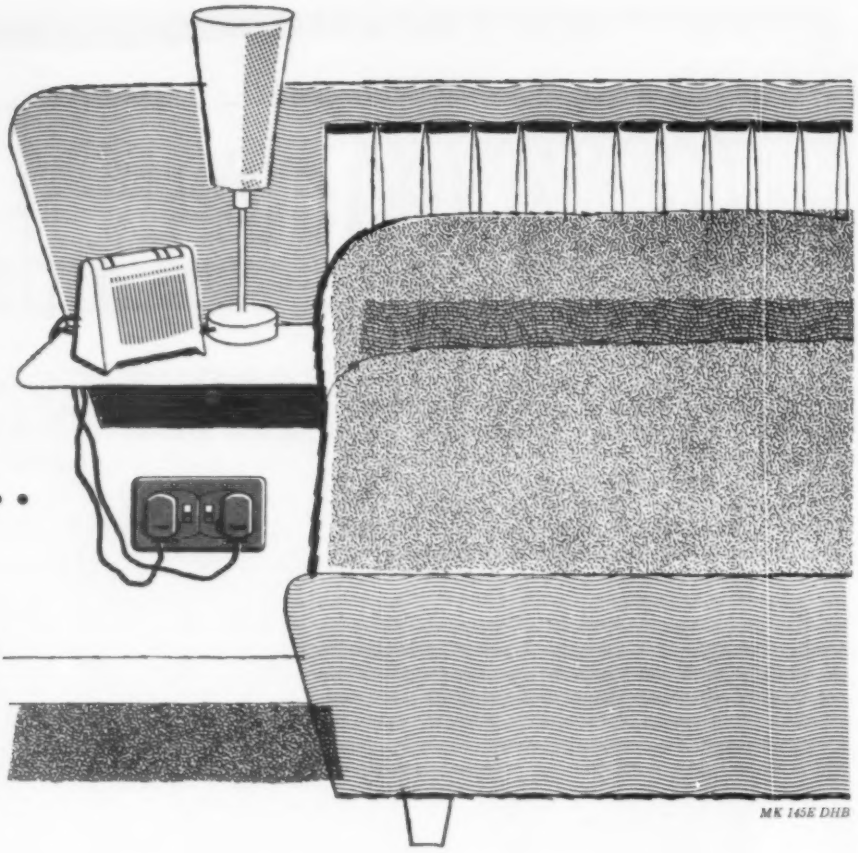
- Readily extended.
- Contactors, either standard or latched-in.
- Magnetic or thermal triple pole over-current relay.
- Earth leakage protection.
- Three phase fault protection by H.R.C. Fuses.
- Local, remote, or sequence control.
- Metering as required.

M. & C. SWITCHGEAR, LTD.

KIRKINTILLOCH, GLASGOW.

LONDON OFFICE, 36 VICTORIA ST., S.W.1. SHEFFIELD OFFICE, OLIVE GROVE RD.

Double the use of each outlet . . .



MK 145E DHB

List No. 2949

List No. 2945

List No. 2946

List No. 2947

List No. 2948

TWIN SWITCHSOCKET-OUTLETS ARE THE ANSWER

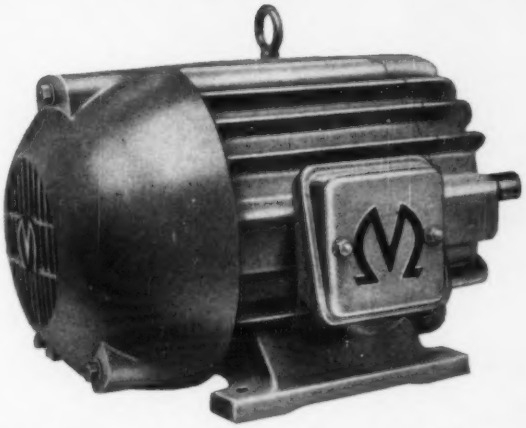
In the planning of an electrical installation, there are certain 'natural' sites for socket-outlets. At the bedside, over the kitchen work top and on both sides of the fireplace are just three instances.

The fullest use of these natural sites can be obtained by using the new MK twin switchsocket-outlets. MK twin units double the efficiency of every installation at low cost. These new MK designs have switch control on both sockets.

The new range includes surface and flush all-insulated patterns as well as surface metalclad and flush metal units. The flush patterns have the same fixing-centres as the MK twin unswitched sockets. The two outlets are interconnected so that only one set of terminals is needed—a great saving on installation time.

MK . . . the mark of leadership

M. K. Electric Limited, Wakefield Street, London N.18 England



T.E.F.C. S.C. INDUCTION MOTORS

4 POLE—50 CYCLES—55°C RISE

OUTPUTS USING GRADED DOUBLE LAYER STATOR WINDING

PATENT No. 644676

B.S.S. 2083			MAWDSLEY'S
B. 225	5 B.H.P.	or 7½ B.H.P.	B. 225
B. 254	7½ B.H.P.	„ 10 B.H.P.	B. 254
B. 284	10 B.H.P.	„ 15 B.H.P.	B. 284
B. 324	15 B.H.P.	„ 20 B.H.P.	B. 324
B. 326	20 B.H.P.	„ 30 B.H.P.	B. 326

BOTH OUTPUTS AVAILABLE

NOW!

MARINE

Generators and Motors for all ships' auxiliaries up to 300 kW at 500 r.p.m.

ALTERNATORS

All types including Fully Compensated, Patent No. 571968. 3–200 kVA at 1,000 and 1,500 r.p.m.

INDUSTRIAL

D.C. Motors and Generators all types ½–300 kW or B.H.P. A.C. T.E. Fan Cooled Type (only) 1½–120 B.H.P. including Motors to B.S. 2083.

SPECIALS

Sales Engineers available for immediate consultation.

MAWDSLEY'S LTD

ZONE WORKS · DURSLEY · GLOUCESTERSHIRE · Telephone: DURSLEY 2386 (5 lines) · Grams: ZONE, DURSLEY

London Office: 28, QUEEN ANNE'S GATE, WESTMINSTER, S.W.1. Telephone: WHitehall 8892

FIVE MILLION GALLONS A DAY...

. . . . against a 551 ft. head is the output of this high-pressure waterworks pump, which is one of the largest in the United Kingdom. It is driven by a Mather & Platt 775 h.p. 400 V synchronous motor at 1,000 r.p.m.

Write for descriptive literature to:—

Mather & Platt
LIMITED

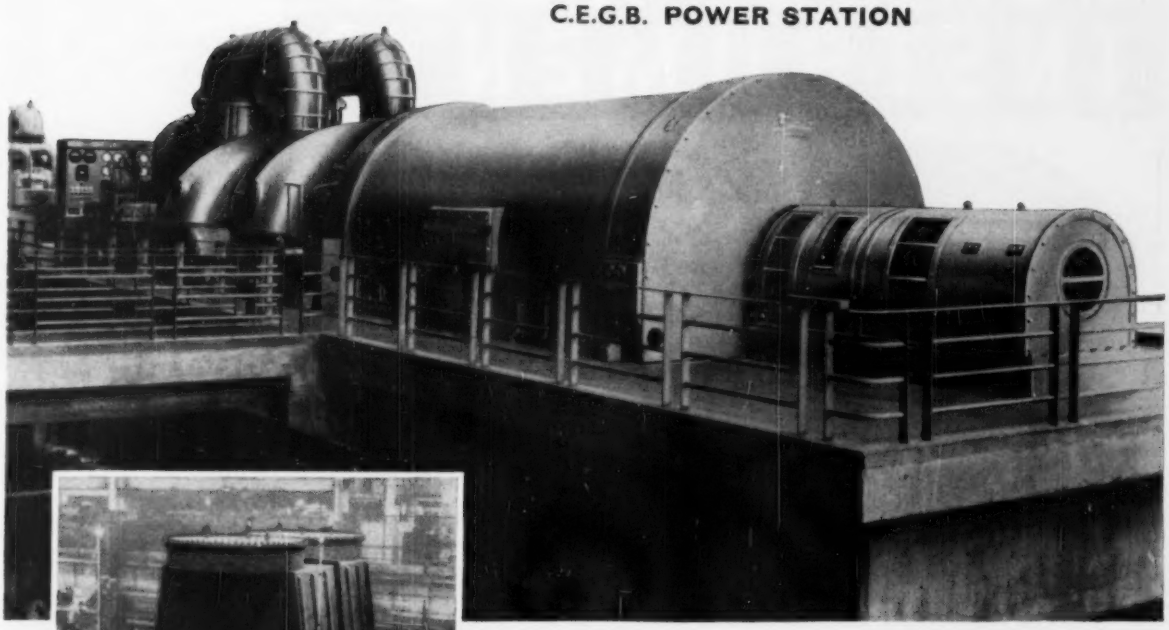
PARK WORKS · MANCHESTER 10

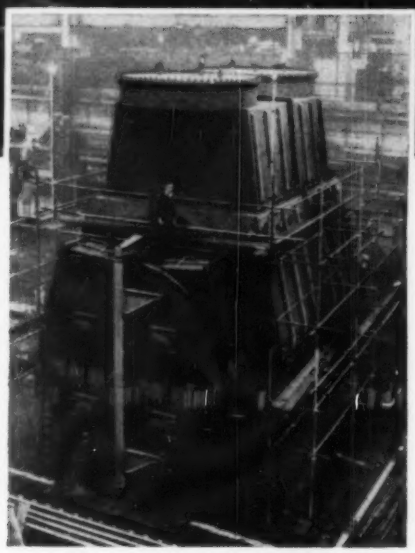
Telephone: COLlyhurst 2321. Telegrams: MATHER, MANCHESTER

766

Power for the Grid–Portishead 'B'

C.E.G.B. POWER STATION





Metropolitan-Vickers are to supply six 60 MW steam turbine-generating sets to the Portishead "B" Power Station. These two-cylinder close-coupled steam turbines drive 75 MVA hydrogen-cooled generators, and the first two sets are now in service. The turbines are suitable for two-shift operation and are direct-coupled to the generators, which produce 50 cycle, 3-phase current at 11,800 volts.

The turbines have initial steam conditions of 900 psig, 900°F, and exhaust to single-shell central flow condensers which, in this station, have to be installed some 69 ft. below the turbines. The condensers, together with the five-stage feed water heating equipment are also being supplied by Metropolitan-Vickers.

The illustration shows a single-shell condenser under construction. Six of these units, each having a cooling surface area of 60,000 sq. ft., are being supplied for the installation.

METROPOLITAN-VICKERS
ELECTRICAL CO LTD · TRAFFORD PARK · MANCHESTER 17

An A.E.I. Company

Leading Electrical Progress

B/B604

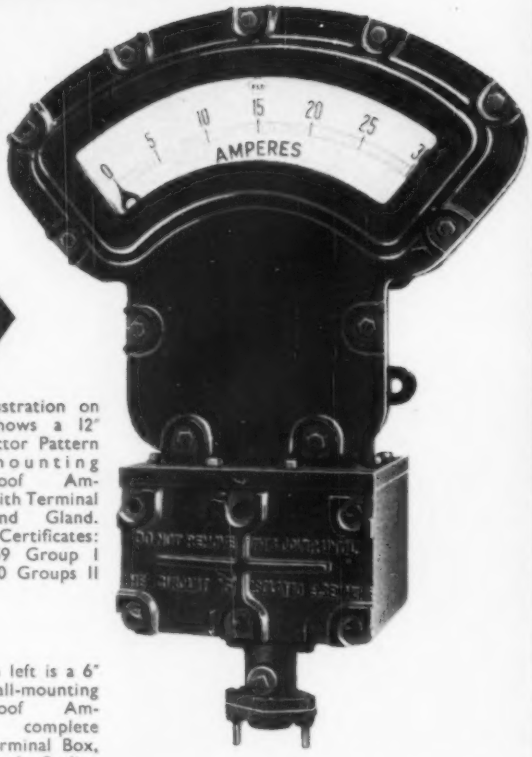
NALDERS

FLAMEPROOF INSTRUMENTS

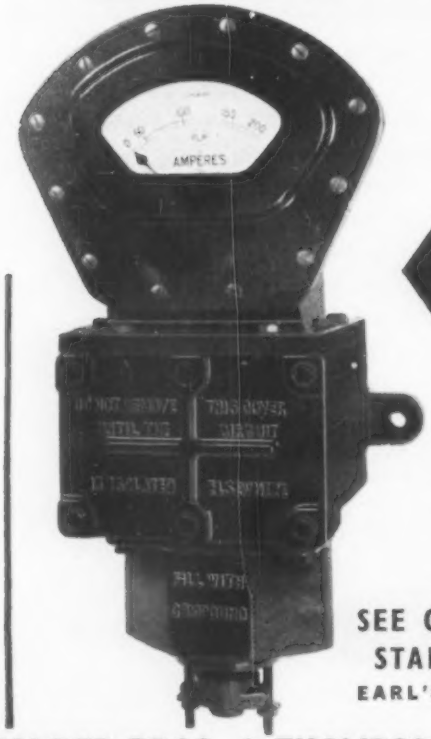
FLP

CONFORM TO B.S. SPECIFICATION & BUXTON TESTS

Illustrated above is a Controller type Flameproof Instrument, with a 6" dial. Buxton Certificates: FLP 2097 Group I FLP 2098 Groups II & III.



The illustration on right shows a 12" dial, Sector Pattern Wall-mounting Flameproof Ammeter with Terminal Box and Gland. Buxton Certificates: FLP 3759 Group I FLP 3760 Groups II & III.



Seen on left is a 6" dial, Wall-mounting Flameproof Ammeter, complete with Terminal Box, Compound Sealing Chamber and Gland. Buxton Certificates: FLP 1004/2 Groups I II & III.

The photograph below shows a Controller type Flameproof Instrument, with a 4" dial. Buxton Certificates: FLP 1053 Group I FLP 2690 Groups II & III.

NALDERS PRODUCTS include: **PROTECTIVE RELAYS, VECTORMETERS, AUTOMATIC EARTH PROVING SUPPLY SWITCHES, "BIJOU" CIRCUIT BREAKERS, etc.**

SEE OUR STAND **K17** (A. S. E. E.) ELECTRICAL ENGINEERING EXHIBITION EARL'S COURT 25-29 MARCH

NALDER BROS. & THOMPSON LTD. Dalston Lane Works, London, E.8

TELEGRAMS: OCCLUDE HACK LONDON TELEPHONE: CLISSOLD 2365 (4 lines)

BMJ

First with Micanite and still leading

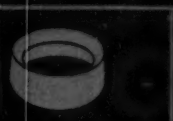
Since introducing Micanite (built-up mica) insulation to the electrical industry over 50 years ago, we have constantly developed new manufacturing methods and new grades of material to meet every demand.
If you have any problems, take us into your confidence — we are specialists with more than half a century of practical experience.

THESE ARE OUR BASIC GRADES OF MICANITE:—

Commutator.
Hard.
Flexible.
Moulding.
Heat Resisting.
High Heat.
Silicone.
Micanite cloth and paper.
Micafolium.
Mica tapes.

THESE ARE OUR PRINCIPAL MICANITE PRODUCTS:—

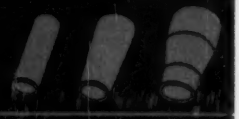
V-RINGS.



COVERED BARS.

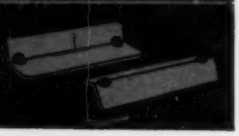
SEGMENT SEPARATORS.

TUBES. CYLINDERS.



SHEETS.

MOULDINGS. FABRICATED PARTS.



WE MAKE EVERY TYPE OF MICANITE INSULATION

If you would like further information, please write for a copy of our booklet "Mica and Micanite".

m and i

the electrical insulation people

THE MICANITE & INSULATORS CO., LTD.,
Blackhorse Lane, Walthamstow, London, E.17. Tel: Larkswood 5500.
Grams: "Mytilite", Easphone, London.

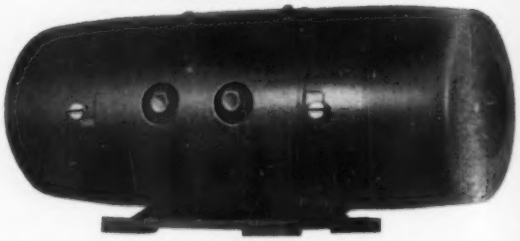
NEWTON-DERBY

ELECTRICAL PLANT SPECIALISTS

AIRCRAFT GENERATORS
ROTARY TRANSFORMERS
HIGH FREQUENCY ALTERNATORS
AUTOMATIC CARBON PILE VOLTAGE REGULATORS

YOUR ENQUIRIES INVITED

LITERATURE ON REQUEST



Rotary Transformer Frame D.2.2.
Up to 100 watts output, weight 5¾ lb.

NEWTON BROTHERS (DERBY) LTD.
HEAD OFFICE & WORKS: ALFRETON RD., DERBY. PHONE: DERBY 47676 (4 LINES). GRAMS: DYNAMO, DERBY
LONDON OFFICE: IMPERIAL BUILDINGS, 56 KINGSWAY, W.C.2

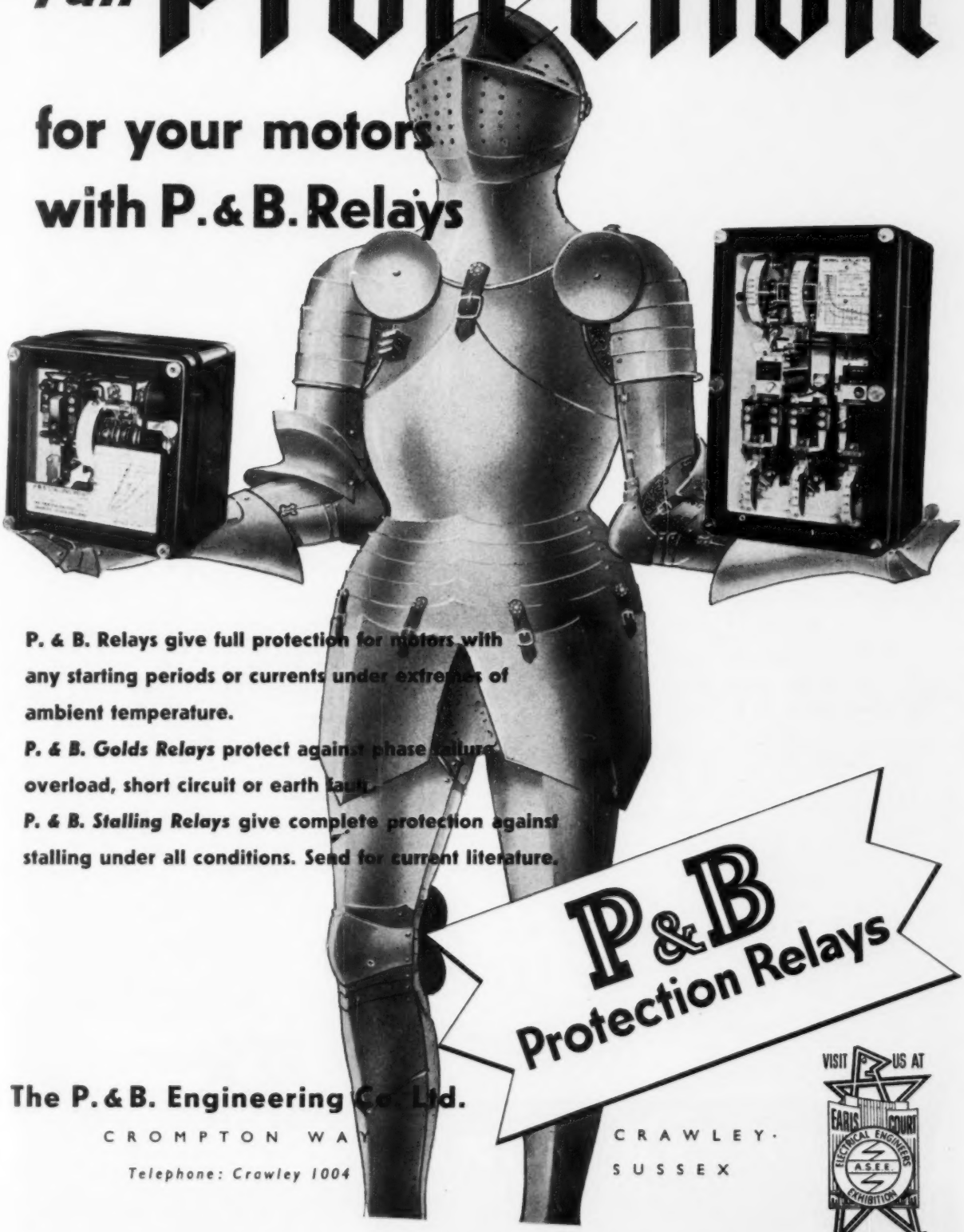
PREMIER
COOLING TOWERS

Due to their special type of construction, PREMIER Cooling Towers are acclaimed by engineers as being the most efficient. Used under widely varying conditions in important power stations throughout the world, PREMIER Towers are giving complete satisfaction.

THE PREMIER COOLER & ENGINEERING CO., LTD.,
SHALFORD, near GUILDFORD, SURREY

Full Protection

for your motors with P. & B. Relays



P. & B. Relays give full protection for motors with any starting periods or currents under extremes of ambient temperature.

P. & B. Golds Relays **protect against phase failure, overload, short circuit or earth fault.**

P. & B. Stalling Relays **give complete protection against stalling under all conditions. Send for current literature.**

P & B Protection Relays

The P. & B. Engineering Co. Ltd.

CROMPTON WAY CRAWLEY · SUSSEX

Telephone: Crawley 1004

VISIT US AT EARLS COURT ELECTRICAL ENGINEERS EXHIBITION A.S.E.E. MARCH 25TH to 29TH 1958

SPENCERISMS

Did you hear of the Highwayman

Who caught us up near Leeds?

That was when the Spencer stage ran

Past all record speeds.

Flying thundering hooves drew near,

Our nags collapsed with fright.

The coachman's rising shriek of fear

Dissolved into the night.

A thousand deaths we must have died —

The villain watched us quiver.

"I only want your wire" he sighed*

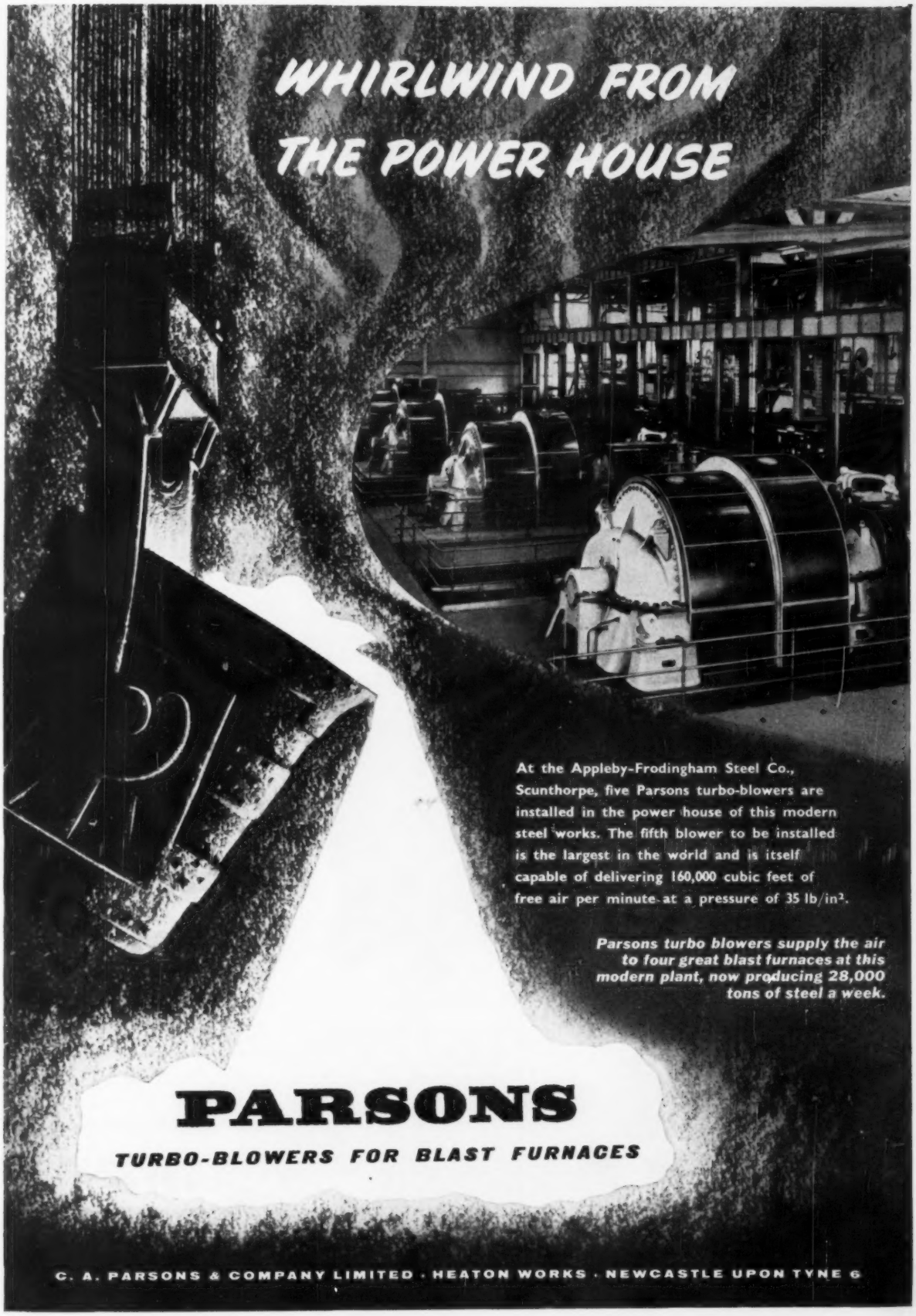
"How soon can you deliver?"

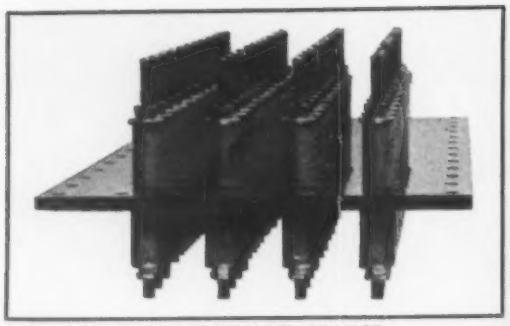
* SPENCERS OF WAKEFIELD have been drawing Wire for over fifty years. A completely modern plant manufactures Wire from Steel, Copper and Aluminium for a wide variety of industrial uses. Also Copper and Aluminium for cables, transformers, motors and the electrical trade generally.

Spencers OF WAKEFIELD

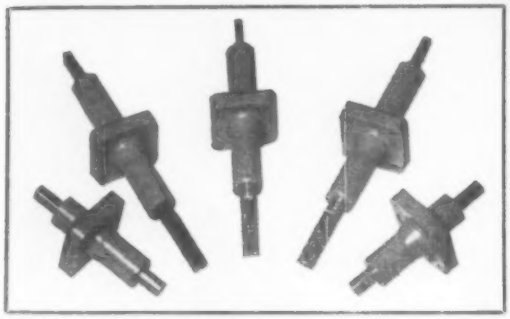
THE
SPENCER WIRE
COMPANY LIMITED • WAKEFIELD
Telephone • WAKEFIELD 6111 (10 lines) • Telegrams • SPENCER, WAKEFIELD, TELEX
Telex No. 55,160

DaW258 BJ

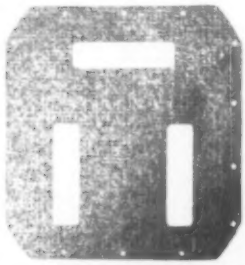

WHIRLWIND FROM
THE POWER HOUSE
At the Appleby-Frodingham Steel Co., Scunthorpe, five Parsons turbo-blowers are installed in the power house of this modern steel works. The fifth blower to be installed is the largest in the world and is itself capable of delivering 160,000 cubic feet of free air per minute at a pressure of 35 lb/in².
Parsons turbo blowers supply the air to four great blast furnaces at this modern plant, now producing 28,000 tons of steel a week.
PARSONS
TURBO-BLOWERS FOR BLAST FURNACES
C. A. PARSONS & COMPANY LIMITED · HEATON WORKS · NEWCASTLE UPON TYNE 6



PERMALI OFFERS A COMPLETE SERVICE
Permali produce the complete job from raw material to finished article—This EHT transformer terminal board, made from a Permali base with Dialam through-bushings, is one of many different components designed, manufactured, machined, assembled and tested entirely by Permali Ltd.

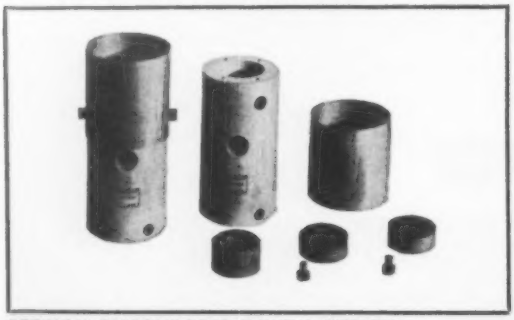


PERMALI LOOKS AHEAD
These cast-resin insulators, now being produced in quantity, constitute another new advance in manufacturing technique —made possible by constant research and development in the Permali laboratories.



PERMALI FOR PRECISION
This 132 kV arc-control device demonstrates the machineability and strength of Permali. Note how simply metal fittings can be combined with the material.

PERMALI CATERS FOR SPECIAL OPERATING CONDITIONS
Made from Grade TH material, this bus barrier board is specially moisture resisting for tropical and high humidity applications.



PERMALI ENCOURAGES SKILFUL DESIGN
Combining Dialam S.R.B. fabric and paper tubes together with Permali throat plates and studs, these 33 kV arc control devices employ Permali manufactured materials to their best advantage.

PERMALI OFFERS NEW POSSIBILITIES
New design opportunities are opened up with Permaglass glass-fibre reinforced laminates. This welding transformer cover is typical of the many products for which this unique material is suited.

When you need

INSULATION

. . . use the

PERMALI

COMPLETE

SERVICE

for the design and development of components in:—

PERMALI — the insulating material outstanding for strength
PERMAGLASS — Glass fibre reinforced plastics
PERMAFLON — the P.T.F.E. plastic material with a unique combination of properties.
DIALAM — S.R.B. Paper and Fabric tubes.

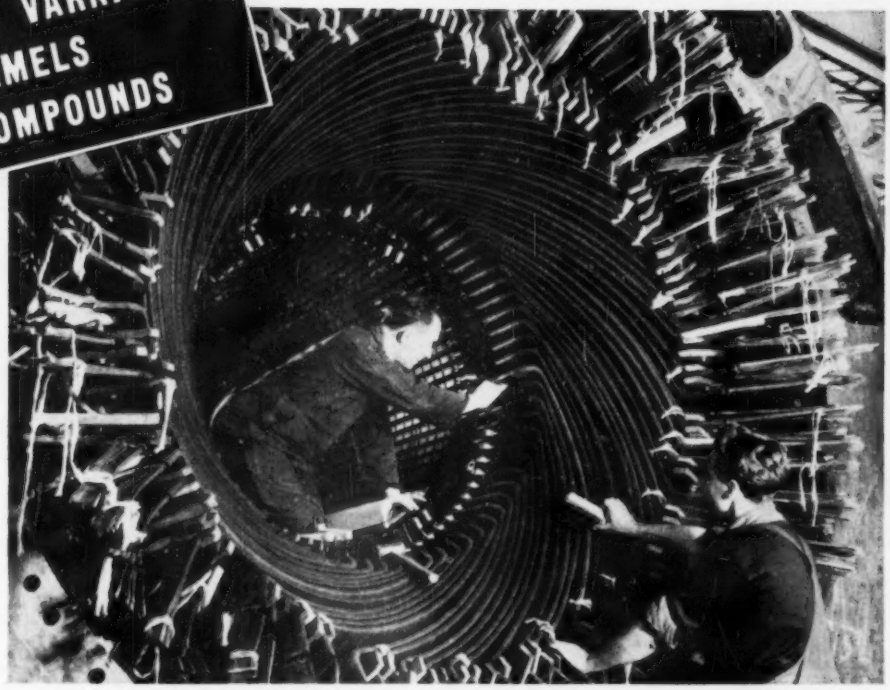
Grades EH and TH Permali are MoS, Admiralty, G.P.O., K.E.M.A. approved, fully meet BS 2572 and Def 5,000.

KEEP ABREAST OF NEW DEVELOPMENTS *and write for the latest technical data—or send us your print for quotation.*

PERMALI LIMITED

Bristol Road · Gloucester · England · Telephone 24941

MINERVA
INSULATING VARNISHES ENAMELS AND COMPOUNDS



A Stator under construction

By kind permission of C. A. PARSONS & CO. LTD. Newcastle-on-Tyne.

We are constantly developing Special Varnishes to meet the many and varied requirements of the Electrical Industry. The tendency has been to concentrate on the development of Varnishes utilising Synthetic Resins. The advent of these Synthetic Types of Insulating Varnishes which have been developed by constant research over many years in our Chemical, Electrical and Physical Laboratories has enabled us to produce Insulating Varnishes to meet the most exacting requirements set by the Electrical Industry, thereby maintaining the high reputation and standard of 'MINERVA' Insulating Products.

Catalogue post free

STOVING VARNISHES (Natural Resin Type)
STOVING VARNISHES (Synthetic Resin Type)
THERMO-SETTING VARNISHES
SOLVENTLESS VARNISHES
AIR-DRYING VARNISHES
CLOTH VARNISHES
CORE-PLATE VARNISHES (Stoving and Air-Drying)
COPPER WIRE ENAMELS (Oleo-resinous and Synthetic Types)
All the above are supplied in black and clear.
ACID & HEAT RESISTING ENAMELS
Available in all colours
MICA BONDING VARNISHES
COIL STICKING VARNISHES
SLEEVING VARNISHES (Black, Clear and Colours)
CABLE LACQUERS (Non-flam., Cellulose Type and P.V.C.)
COMPOUNDS (Various Types)

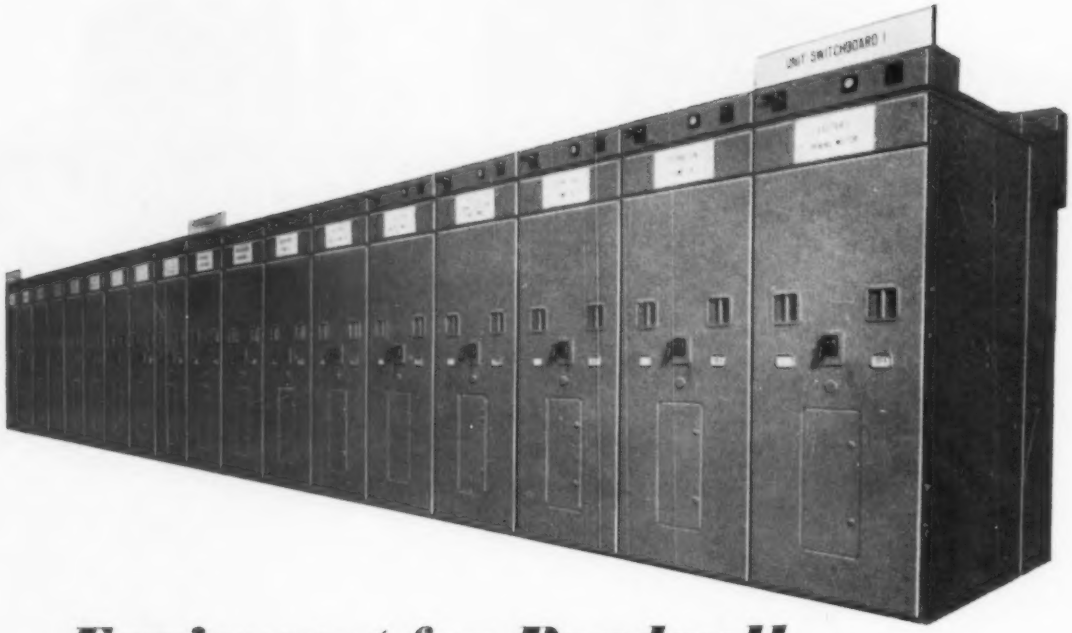
All the materials listed conform to B.S. Specifications wherever applicable

Pinchin, Johnson & Co.

4 CARLTON GARDENS, LONDON, S.W.1

Telephone: TRAfalgar 5600

Branches: BELFAST, BIRMINGHAM, BOOTLE, BRIGHTON, BRISTOL, GLASGOW, LEEDS, MANCHESTER, NEWCASTLE-ON-TYNE & SOUTHAMPTON



Equipment for Bradwell

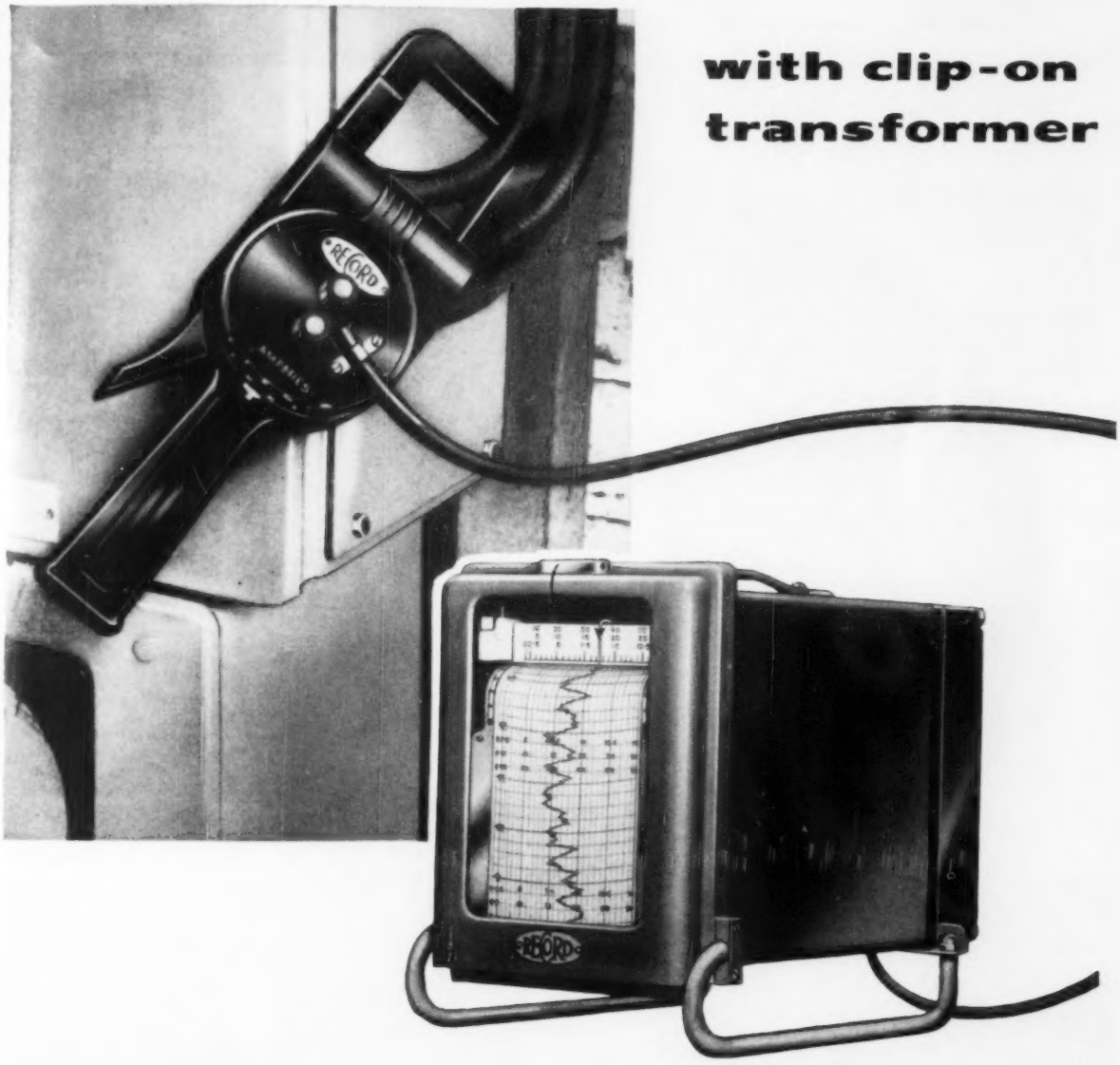
All the switchgear comprising the main 132-kV air-blast circuit-breakers, 6·6-kV, 3·3-kV, and 415-volt air-break equipment for auxiliary supplies, together with its associated control apparatus for Bradwell Nuclear Power Station is being supplied by Reyrolle who are responsible also for the reactor control-rod heads, the fission-products detection equipment, and the machining of the graphite blocks.

Reyrolle specialists in switchgear and control-apparatus

A. Reyrolle & Company Limited · Hebburn · County Durham · England

RECORD Graphic Recorder

with clip-on transformer



The combination shown provides 7 current ranges up to 600A. In addition the Recorder is provided with self-contained voltage ranges of 150, 300 and 600V. The whole forms an easily transportable Universal A.C. Recorder which is accurate, responsive and robust. Send for details.

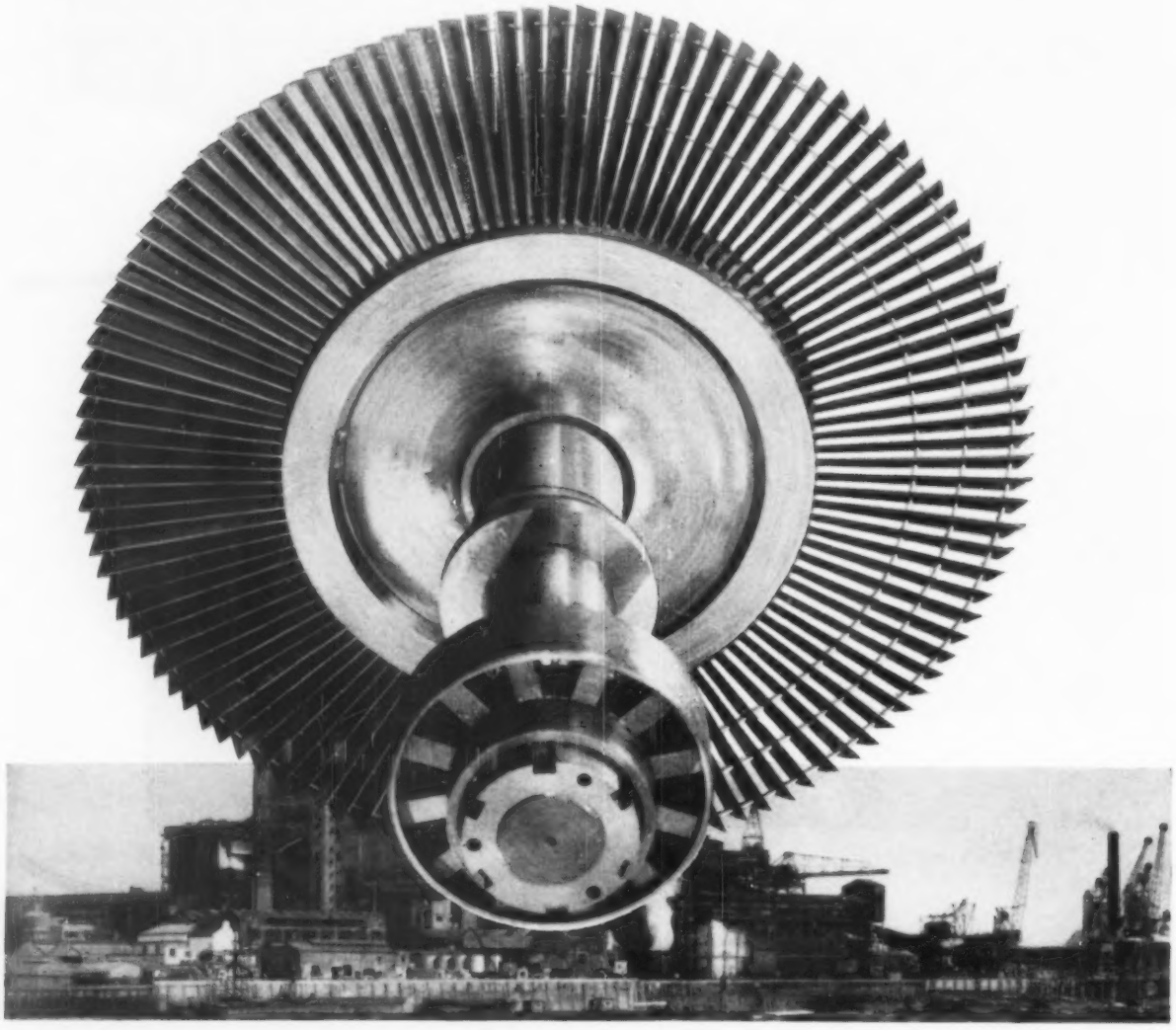
THE RECORD ELECTRICAL COMPANY LIMITED

"CIRSCALE WORKS" · BROADHEATH · ALTRINCHAM · CHESHIRE

C2118

The Richardsons Westgarth Group

Constructors of some of the most efficient generating plant operating in the United Kingdom — for both public electricity supply and industry. Manufacturers of boilers, steam and gas turbines and alternators; condensing and feed heating plant, axial and centrifugal blowers and gas exhausters; cooling water strainers and sea water evaporating plant.

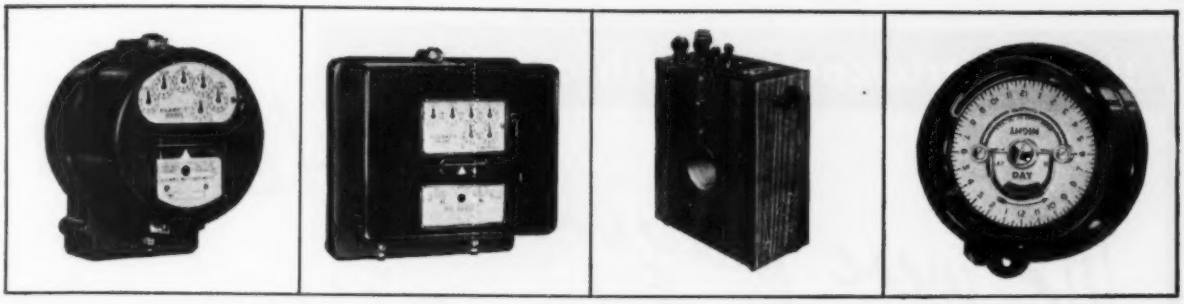


Co-ordinating the activities of:—

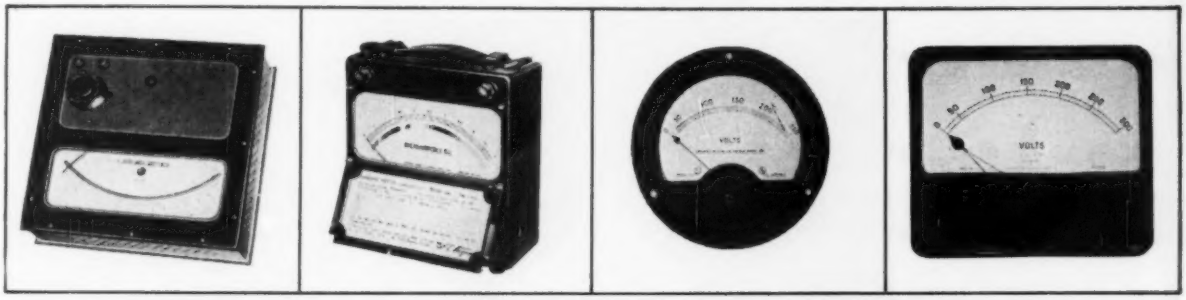
THE NORTH EASTERN MARINE ENGINEERING CO. LTD.
PARSONS MARINE TURBINE CO. LTD.
GEORGE CLARK & NORTH EASTERN MARINE (SUNDERLAND) LTD.
RICHARDSONS WESTGARTH (HARTLEPOOL) LTD.
THE HUMBER GRAVING DOCK & ENGINEERING CO. LTD.
RICHARDSONS WESTGARTH ATOMIC LTD.

ASSOCIATED COMPANY: ATOMIC POWER CONSTRUCTIONS LTD.

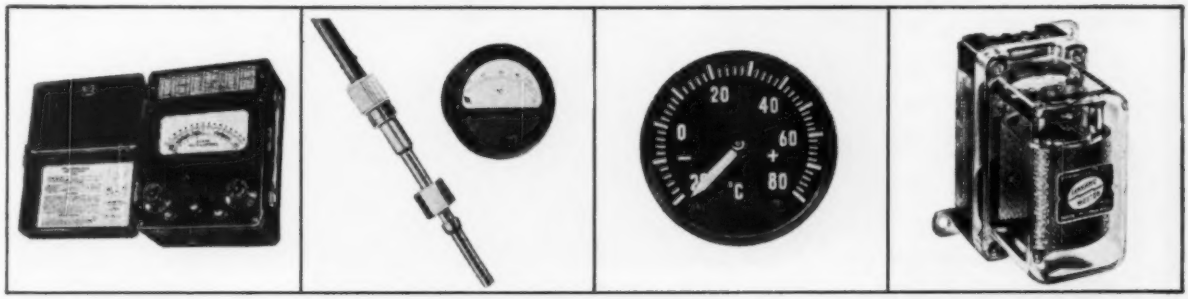
RICHARDSONS, WESTGARTH & CO. LTD., WALLSEND, NORTHUMBERLAND



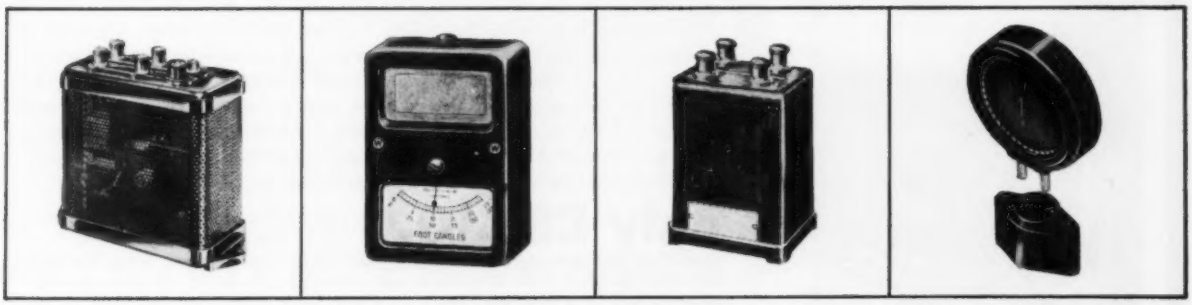
ELECTRICITY METERS | CURRENT TRANSFORMERS | TIME SWITCHES



LABORATORY STANDARDS | PORTABLE INSTRUMENTS | PANEL AND SWITCHBOARD INSTRUMENTS



ALL-PURPOSE TEST INSTRUMENTS | THERMOMETRY | AIRCRAFT INSTRUMENTS | MOVING COIL RELAYS



ELECTRONIC MEASURING AIDS | ILLUMINATION METERS | WESTON STANDARD CELLS | PHOTO-ELECTRIC CELLS

SANGAMO WESTON LIMITED

ENFIELD, MIDDLESEX Tel: Enfield 3434 (6 lines) and 1242 (6 lines)
Grams: Sanwest, Enfield

SCOTTISH FACTORY: PORT GLASGOW, RENFREWSHIRE
PORT GLASGOW 41151

Branches: London, Glasgow, Newcastle, Leeds
Manchester, Liverpool, Nottingham, Wolverhampton
Bristol, Southampton, Brighton

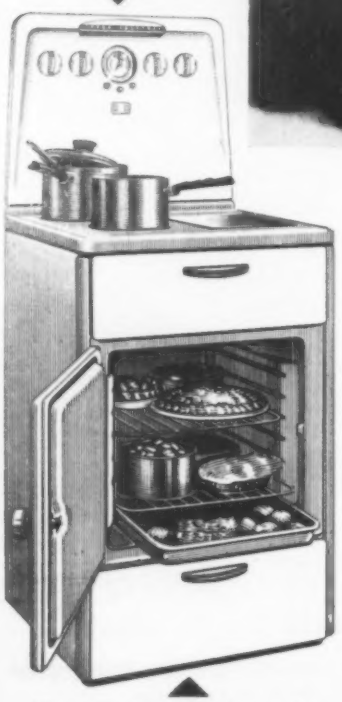
SW/8

the electric cooker with a memory

We were playing in the park

as the dinner switched itself on!

All Creda electric cookers have to be exhaustively tested and approved by the Creda department of Home Economics before they are put into production



New auto-timed plate warming drawer — as standard

She's free to go where she pleases—

Other housewives are in their kitchens. Yet when she reaches home, dinner will be in the oven—piping hot, freshly cooked, ready to serve on warm plates! How is it done? With the cooker with a memory—the incredible new auto-timed Creda Carefree electric cooker. Prepare a complete meal, put it in the oven, set the simple control—and you're free! The Creda Carefree's oven switches itself on . . . does the cooking . . . switches itself off—all automatically! Good looking—lavishly equipped—large oven—isn't the Creda Carefree just the cooker for you?

only £55.10.0 No purchase tax
Glass oven door — optional extra

Including the new rapid boiling radiant plate — as standard. From the fastest boil to the gentlest simmer thanks to auto control

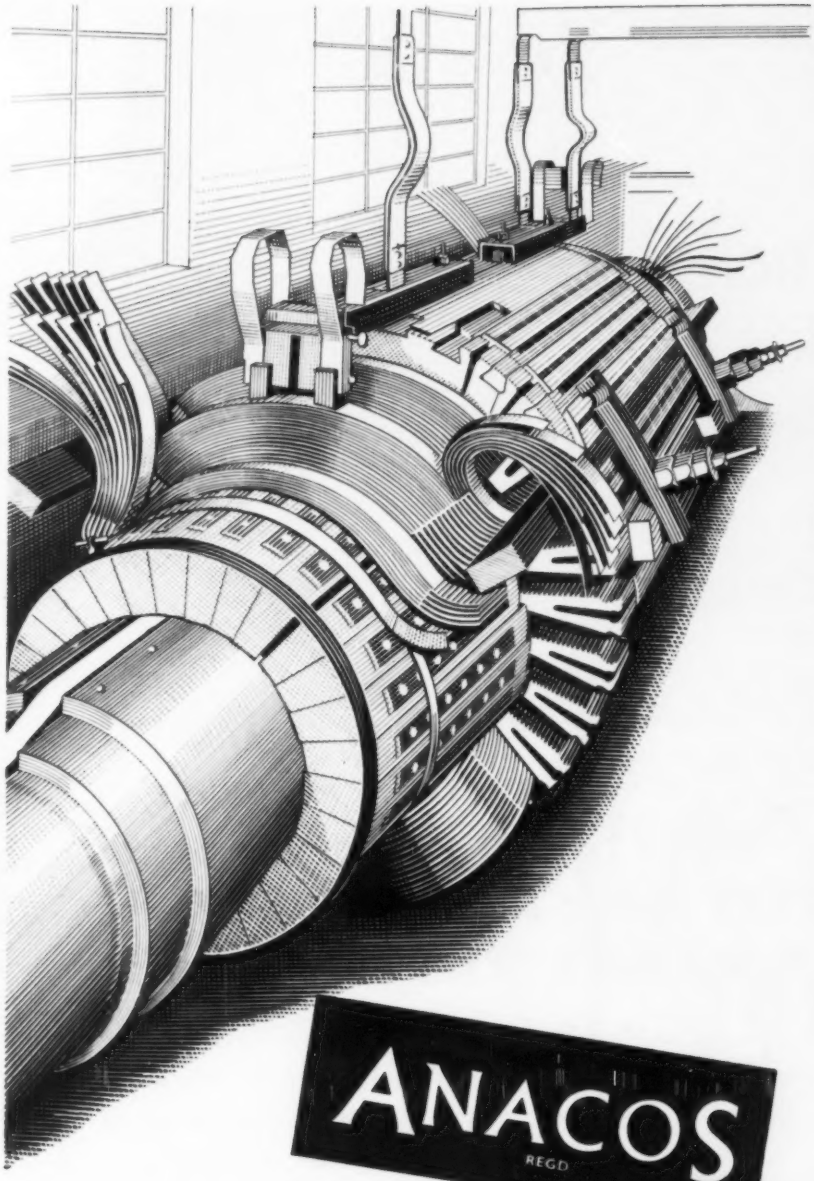
and now — COLOUR! Attractive overall pastel shades of turquoise, blue or green (at slight extra cost) as well as the popular white or cream. Option of coloured hobs in turquoise, blue or green, no extra

for electric cooking—for cheaper—quicker—cleaner cooking—you need—a

Creda Carefree

Simplex Electric Co Ltd Creda Works Blythe Bridge Staffs
London Showrooms: Creda House Binney St (off Oxford St) London W1

A Company



Power behind Power

This rotor for a turbo-alternator is being wound with half coils of copper-silver alloy strip which finally will be united into complete coils by silver soldering.

'Anacos' Copper Strip maintains those precise qualities that are needed for reliability at all times.

ANACOS REGD
COPPER STRIP

FREDERICK SMITH & CO.

Manufacturers of 'Anacos' Copper and Copper Alloy Conductors

ANACONDA WORKS · SALFORD 3 · LANCS

BARE AND INSULATED ELECTRICAL CONDUCTORS OF ALL TYPES

THE LONDON ELECTRIC WIRE COMPANY AND SMITHS LIMITED	FREDERICK SMITH & CO.	THE LIVERPOOL ELECTRIC CABLE CO. LTD.	YACTITE WIRE CO. LTD.

IN CONDITIONS LIKE THESE...

N

W

E

S

THE LIFE OF ROTATING ELECTRICAL MACHINERY DEPENDS ON THE QUALITY OF THE INSULATING VARNISH

All grades of Sterling electrical insulating varnishes are individually blended to suit the varying conditions under which motors operate in many different parts of the world where so much depends on the varnish. Sterling chemists have to consider — and combat — such diverse factors as extremely high or low temperatures, tropical service, presence of abrasives, alkalis, acids, etc.

Write for details — we shall be pleased to advise you without obligation.

MADE BY CHEMISTS

Sterling

INSULATING VARNISHES

SERVICED BY ENGINEERS

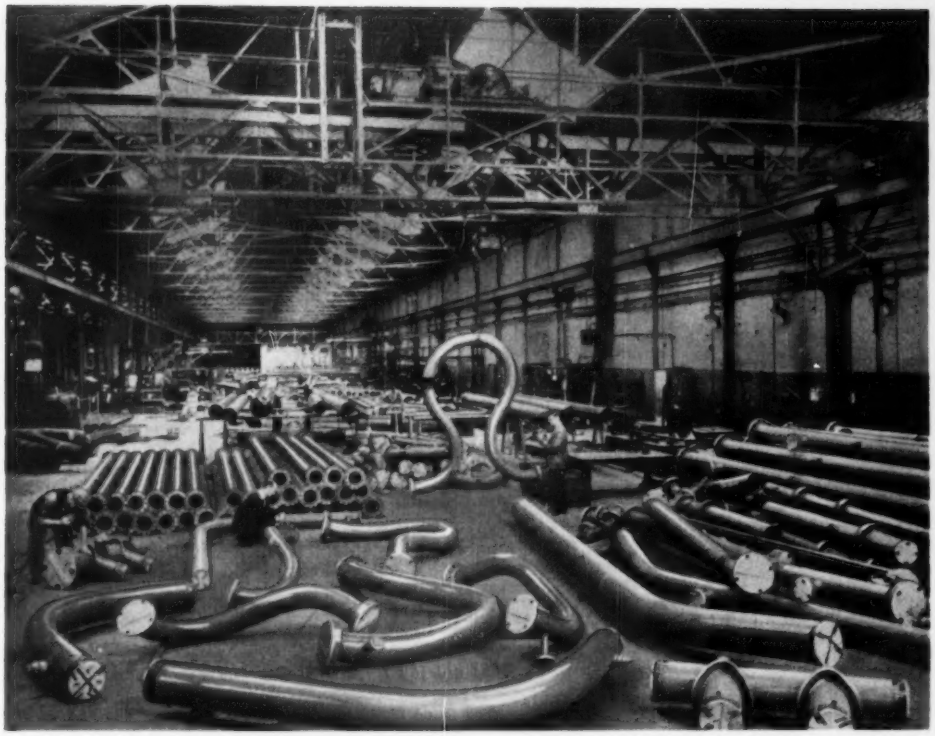
SPECIALISTS IN INSULATION

THE STERLING VARNISH CO LTD FRASER RD TRAFFORD PARK MANCHESTER 17

Telephone: TRAfford Park 0282 (4 lines) *Telegrams: "DIELECTRIC MANCHESTER"*

London Office & Warehouse: 6 LONDON ROAD, BRENTFORD, MIDDLESEX. Telephone Ealing 9152

dm ST9



Manipulated high pressure pipework in the assembly, inspection and despatch bays at Stewarts and Lloyds' Tollcross works

STEEL TUBES AND MANIPULATED PIPEWORK FOR NUCLEAR POWER STATIONS

Stewarts and Lloyds have already contributed substantially to the construction of Britain's new nuclear power stations, in which large quantities of steel tubes and manipulated pipework are required.

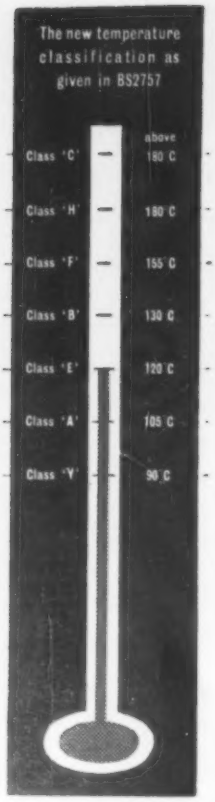
Contracts in hand include material to be supplied to all nuclear power stations now under construction.

Stewarts and Lloyds design, manufacture and install pipework for all types of industrial plants.

STEWARTS AND LLOYDS LIMITED

GLASGOW · BIRMINGHAM · LONDON

The largest manufacturers S&L *of steel tubes in Europe*


The new temperature classification as given in BS2757
above
Class 'C' 180 C
Class 'H' 180 C
Class 'F' 155 C
Class 'B' 130 C
Class 'E' 120 C
Class 'A' 105 C
Class 'Y' 90 C

in a class by itself–

SYMONS' INSULATION

CLASS 'E' MATERIALS

†'Symotex'—the new low priced varnished and untreated 'Terylene'* cloth and tapes from ·007" to ·015" thick

ALSO 'Symax'

Triacetate/Pressboard } combination slot insulation, single
*'Melinex'/Pressboard } sided, double sided and sandwich.

There is a Symons material for all 'Classes'

**'Melinex' and 'Terylene' are the respective I.C.I. registered trade names for Polyethylene Terephthalate film and fibre.*
†'Symotex' is our registered trade name for a new range of untreated and treated 'Terylene' cloths and tapes.

H. D. SYMONS & CO. LTD. Division D, Park Works, Kingston Hill, Surrey
Tel: Kingston 0091. Grams: Insulation 'Phone' Kingston-on-Thames

BEAMA PUBLICATIONS

Problems of Power Transmission at Voltages above 225 kV
by François Cahen, Directeur-Adjoint des Études et Recherches à l'Électricité de France. (Publication No. 146) 5s. net.

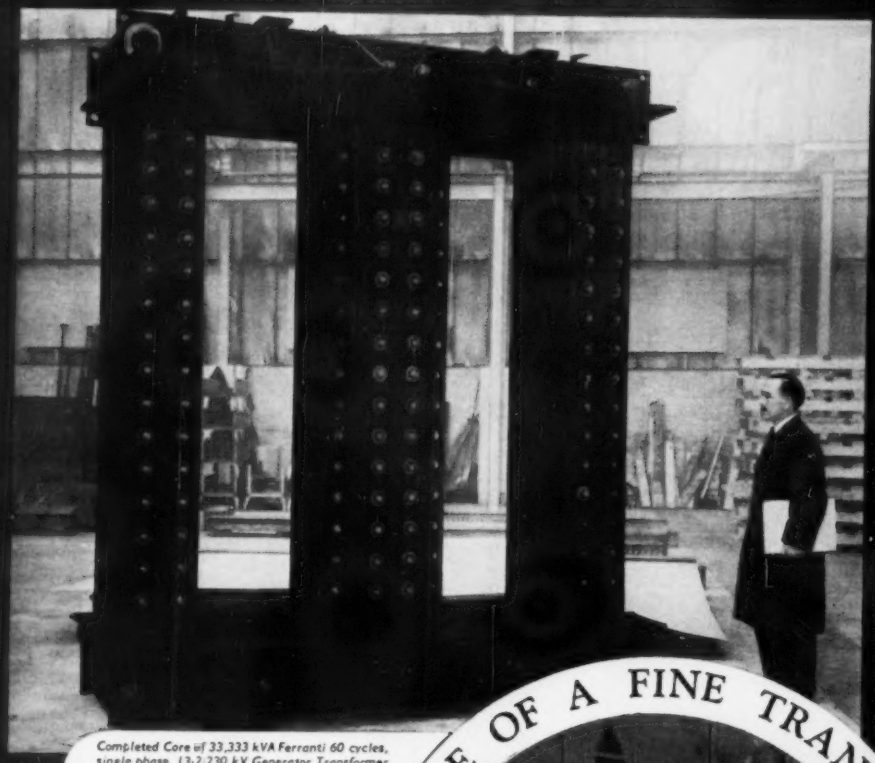
British Electrical Manufacturing
(Publication No. 142) Free on request.

Recommendations for the Insulation Level of Power Transformers
(Publication No. 156) 5s.

Beama Guide to British Electrodes
(Publication No. 144) 5s. net.

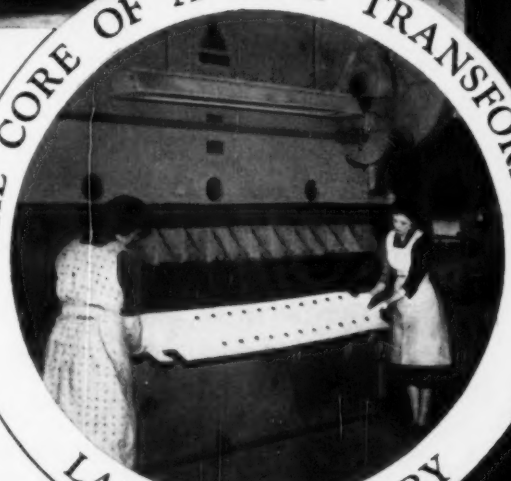
THE BEAMA. A Short Account of its Growth and Activities
(Publication No. 149) Free on request.

The British Electrical & Allied Manufacturers' Association
(Incorporated)
Publications Department: 36 Kingsway, London, W.C.2



Completed Core of 33,333 kVA Ferranti 60 cycles, single phase, 13·2:230 kV Generator Transformer for Garrison Dam, U.S.A.

THE CORE OF A FINE TRANSFORMER



LAMINATIONS BY

LAMINATIONS
of all types, in all sizes and in all grades of material.

FERROSIL
hot-rolled and cold-reduced electrical sheet and strip, and hot-rolled transformer sheet.

ALPHASIL
cold-reduced oriented transformer sheet and strip.

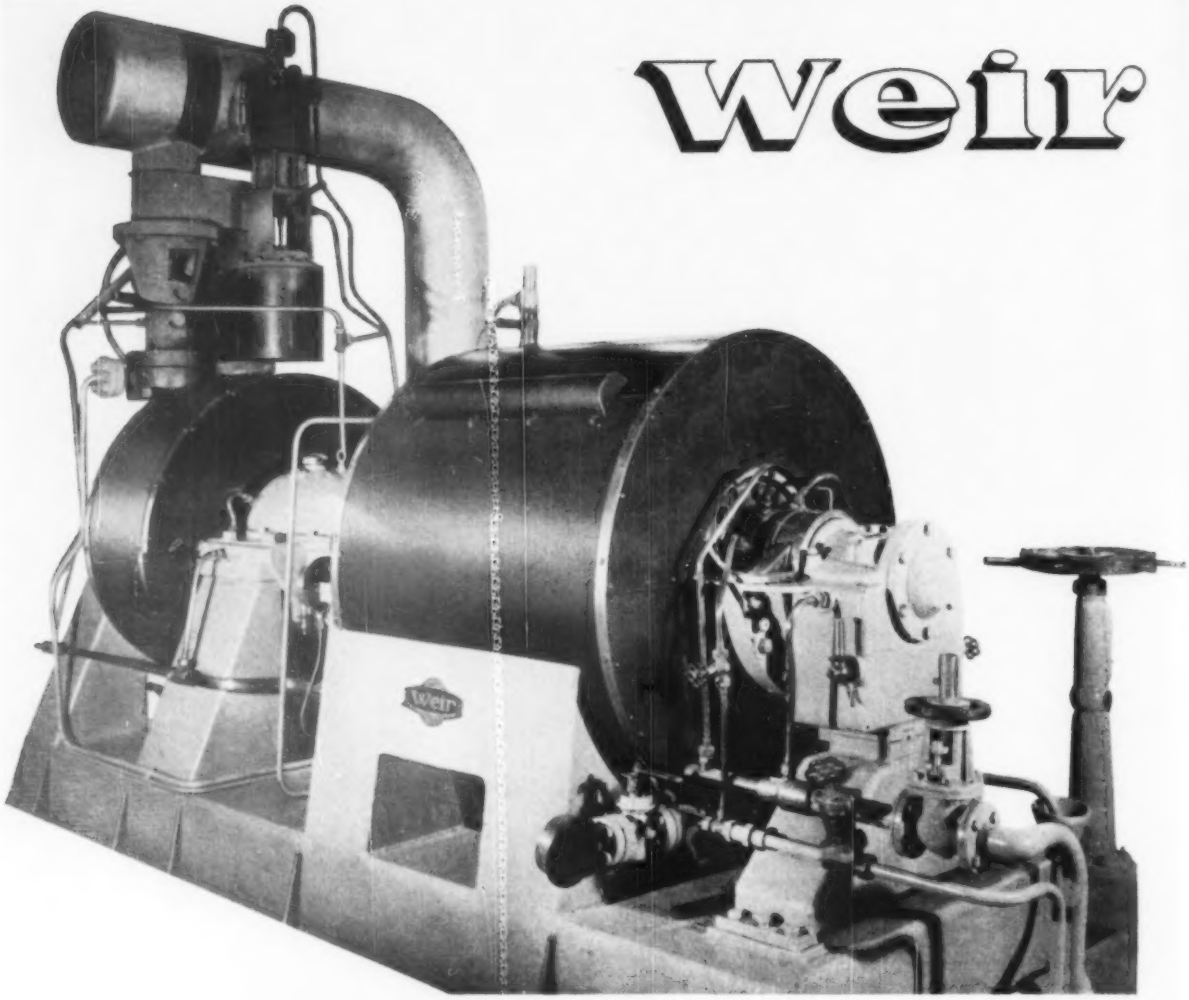
RICHARD THOMAS & BALDWINS LTD.

RTB

Our Cookley Works is one of the largest in Europe specializing in the manufacture of laminations for the electrical industry.

LAMINATION WORKS: Cookley Works, Brierley Hill, Staffs. MIDLAND SECTION OFFICE: Wilden, Stourport-on-Severn, Worcs.
HEAD OFFICE: 47 Park Street, London, W.1

Weir



Turbo-Feed Pumps

are unsurpassed in reliability and are designed to operate in parallel with electrofeeders or other turbo-feed pumps having a falling pressure-capacity characteristic.

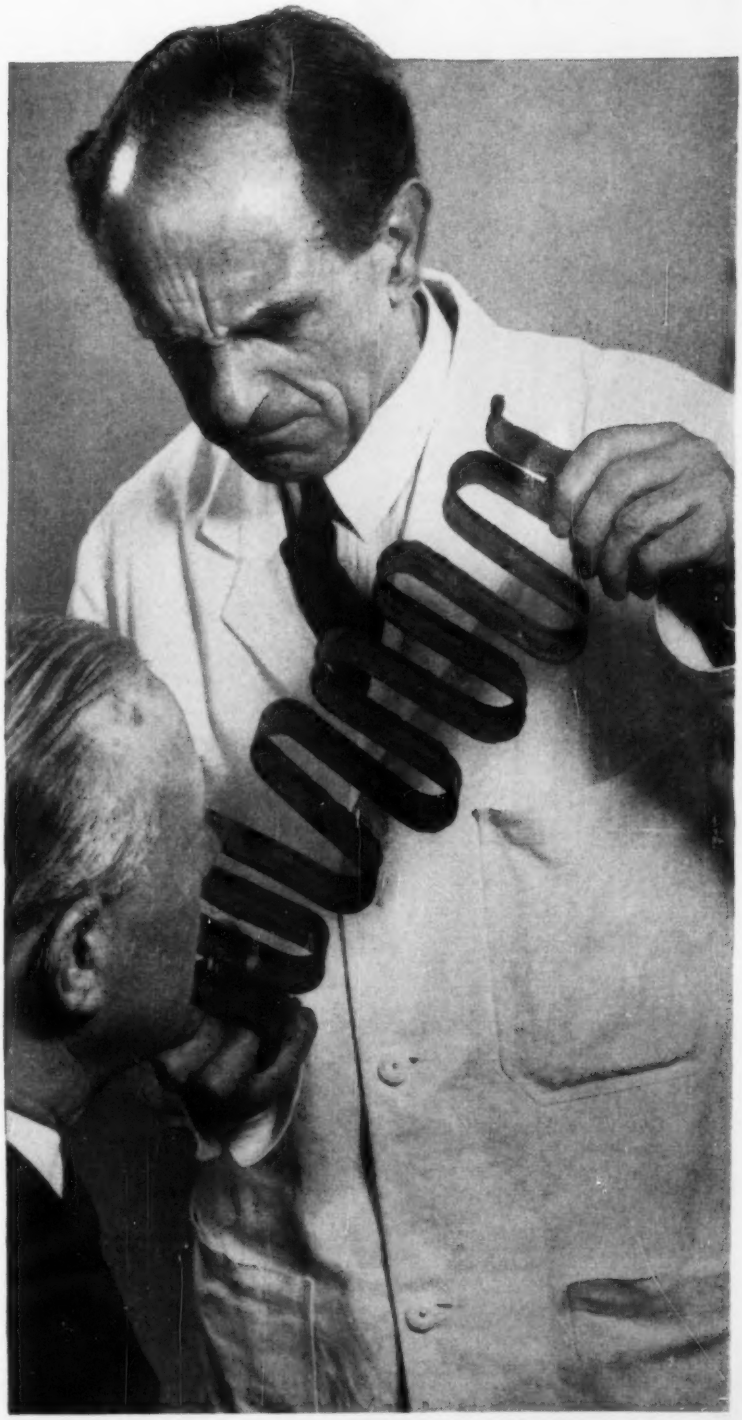
When used as a stand-by pump the Weir cut-in gear automatically brings the turbo-feed pump into immediate operation in the event of electrofeeder failure.

PRODUCTS INCLUDE

FEED HEATERS
DE-AERATORS
FEED REGULATORS
REGENERATIVE CONDENSERS
EVAPORATING & DISTILLING PLANTS
OIL FUEL PUMPS
etc.

G. & J. WEIR LTD
CATHCART : GLASGOW

Mr. Finch is forbidding when he's roused



He's a quiet type normally, all wrapped up in productivity. But when his production line is brought to a standstill by the premature failure of a furnace element, in he rushes to the Buyer's Office. 'Look at this element' he says, and then it starts . . . .

It's little use for the Buyer to protest that he only orders the elements—Mr. Finch is formidable in this mood and, of course, he's right. Correct choice of the most suitable resistance material would have ensured dependability and long life. That is why so many furnace manufacturers use one of the Brightray Alloys for their elements.

BRIGHTRAY

ELECTRICAL RESISTANCE ALLOYS

Produced in the form of Rod, Wire, Strip and Tape

BRIGHTRAY C for intermittent heating up to 1150°C . . . used in cookers, toasters, laundry irons, fires, soldering irons . . .

BRIGHTRAY B produced to provide a cheaper but satisfactory material for elements working up to 950°C.

BRIGHTRAY S for continuous heating up to 1150°C . . . principally intended for electric furnace heating elements . . .

BRIGHTRAY F for electric furnace elements operating in special atmospheres up to 1000°C . . .

WILCO-WIGGIN THERMOMETALS in many grades for thermostatic devices controlling temperatures ranging from −75 to 540°C.

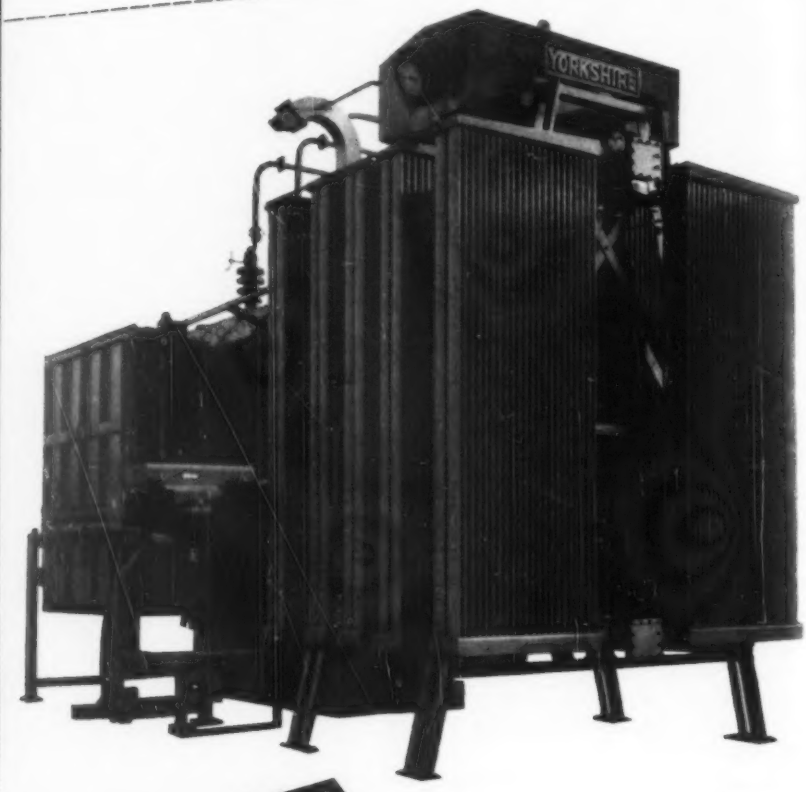
'BRIGHTRAY' AND 'WILCO-WIGGIN' THERMOMETALS ARE REGISTERED TRADE MARKS

HENRY WIGGIN AND COMPANY LIMITED · WIGGIN STREET · BIRMINGHAM 16

TGA ER69

Y·E·T

Constructed by Careful Craftsmen



YORKSHIRE

transformers

We are specialists in the manufacture of **POWER TRANSFORMERS** for Generation, Transmission and Distribution. Every Transformer is entirely manufactured in our own works.

Ratings up to 60,000 k.V.A. Voltages up to 132,000 volts.

YORKSHIRE ELECTRIC TRANSFORMER CO. LTD
THORNHILL, DEWSBURY, ENG. *Tel.* Dewsbury 1691-2

Printed for the Proprietors, THE BRITISH ELECTRICAL AND ALLIED MANUFACTURERS' ASSOCIATION (INCORPORATED), by R. & R. CLARK, LTD., Brandon Street, Edinburgh, and published at 36 Kingsway, London, W.C.2.

The British Electrical and Allied Manufacturers' Association

(INCORPORATED)

36 & 38 KINGSWAY, LONDON, WC2

President

Sir Vincent de Ferranti, MC

Past Presidents

The Rt. Hon. Viscount Chandos, DSO, MC
Sir George Bailey, CBE
Sir George H. Nelson, BART.
Sir Harry Railing

Vice-Presidents, 1957–58

Sir George Bailey, CBE
The Rt. Hon. Viscount Chandos, DSO, MC
E. C. Holroyde, ESQ. (*Vice-Chairman, Crompton Parkinson Ltd; Past-Chairman, The British Electrical & Allied Manufacturers' Association, Inc.*)
W. W. Hughes, ESQ.
Lieut.-Col. R. K. Morcom, CBE, TD (*Chairman, Belliss & Morcom, Ltd; Past-Chairman, The British Electrical & Allied Manufacturers' Association, Inc.*)
The Rt. Hon. The Earl of Mount Edgcumbe (*Director, Everett, Edgcumbe & Co. Ltd*)
Sir George H. Nelson, BART. (*Executive Chairman, The English Electric Co. Ltd; Past-Chairman, The British Electrical & Allied Manufacturers' Association, Inc.*)
Sir Harry Railing (*Director, The General Electric Co. Ltd; Past-Chairman, The British Electrical & Allied Manufacturers' Association, Inc.*)
Sir Alexander Roger, KCIE (*Honorary President, British Insulated Callender's Cables, Ltd*)
V. Watlington, ESQ. (*Past-Chairman and Past-Director, The British Electrical & Allied Manufacturers' Association, Inc.*)
The Rt. Hon. Viscount Weir, GCB (*Honorary President, G. & J. Weir, Ltd*)

Council, 1957–58

CHAIRMAN: J. O. Knowles (*Brookhirst Switchgear Ltd*)

VICE-CHAIRMAN: W. K. G. Allen (*W. H. Allen Sons & Co. Ltd*)

G. B. Alvey (*Mather & Platt Ltd*)
R. F. Archer (*The Micanite & Insulators Co. Ltd*)
C. L. Arnold (*MK Electric Ltd*)
E. H. Ball (*The British Thomson-Houston Co. Ltd*)
J. E. Belliss (*Belliss & Morcom Ltd*)
R. Berry (*Berry's Electric Ltd*)
A. M. Browne (*Hackbridge & Hewittic Electric Co. Ltd*)
A. W. Browne (*Chloride Batteries Ltd*)
J. S. Carter (*Chamberlain & Hookham Ltd*)
C. Dannatt, OBE, MC (*Metropolitan-Vickers Electrical Co. Ltd*)
G. F. Davies (*Hick Hargreaves & Co. Ltd*)
Sir Vincent de Ferranti, MC (*Ferranti Ltd*)
Leslie Gamage, MC (*The General Electric Co. Ltd*)
Sir Claude Gibb, KBE, FRS (*C. A. Parsons & Co. Ltd*)
W. Glass (*Johnson & Phillips Ltd*)
J. H. Hall (*Allen West & Co. Ltd*)
E. C. Holroyde (*Crompton Parkinson Ltd*)
W. B. Laing (*Bruce Peebles & Co. Ltd*)
H. A. Lewis, MBE, TD (*E.M.I. Sales & Service Ltd*)
L. A. Lidstone, JP (*Welding Supplies Ltd*)
I. T. Morrow (*Brush Electrical Engineering Co. Ltd*)
H. H. Mullens (*A. Reyrolle & Co. Ltd*)
Sir George H. Nelson, BART. (*The English Electric Co. Ltd*)
A. G. O'Neill (*Nalder Bros. & Thompson Ltd*)
E. G. Plucknett (*Simplex Electric Co. Ltd*)
A. E. Skan (*George Ellison Ltd*)
S. F. Steward, CBE (*Lancashire Dynamo & Crypto Ltd*)
G. P. Tinker (*Birlec Ltd*)
F. Waine, JP (*British Insulated Callender's Cables Ltd*)
D. D. Walker (*Evershed & Vignoles Ltd*)
J. R. Wilkinson (*Ferguson Pailin Ltd*)
A. Wynn (*Midland Electric Manufacturing Co. Ltd*)

DIRECTOR: B. H. Leeson, CBE, TD, MIEE EXPORT DIRECTOR: D. Maxwell Buist, MIEE, MIEX

SECRETARY: James Oldroyd, TD, MA, FCIS

THE SYMBOL OF QUALITY AND

WORLD-WIDE SERVICE